Before the

Federal Communications Commission

Washington, D.C. 20554

In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3700 MHz Band	)	DA 17-339
	)	GN Docket No. 15-319
	)	GN Docket No. 12-354

To: Marlene H. Dortch

Office of the Secretary, Federal Communications Commission

APPLICATION OF FAIRSPECTRUM LLC TO BE DESIGNATED AS A SPECTRUM ACCESS SYSTEM ADMINISTRATOR

In response to the above-mentioned Public Notice (notice)[1] from the Wireless Telecommunications Bureau and the Office of Engineering and Technology issued on April 7, 2017, Fairspectrum LLC, a wholly owned U.S. subsidiary of Fairspectrum Oy, Finland, hereby submits its proposal to develop and manage an independent Spectrum Access System.

Heikki Kokkinen
Chief Executive Officer
Fairspectrum LLC

Fairspectrum is pleased to offer its proposal to become a SAS Administrator in the Citizens Radio Broadband Service in the 3.5 GHz Band[2]. Fairspectrum compliments the Commission for its pioneer

[1] See The Wireless Telecommunications Bureau (WTB) and the Office of Engineering and Technology (OET) (collectively, WTB/OET) established "second wave" deadline for proposals from prospective Spectrum Access System (SAS) Administrator(s) and Environmental Sensing Capability (ESC) operator(s) in the 3550-3700 MHz band (3.5 GHz Band) as directed by the *Report and Order and Second Further Notice of Proposed Rulemaking*, GN Docket 12-354 (*3.5 GHz First Order*), 30 FCC Rcd 3959, 4067, 4070-4071, paras. 372, 386; 47 C.F.R. §§ 96.1 *et seq*.

[2] FCC 15-47 "Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band,"GN Docket 12-354, FCC 15-47, Report and Order and Second Notice of Proposed Rulemaking, Released April 21,

work in the area of Dynamic Spectrum Access and for the enabled possibilities of new consumer and business communication services in the band.

Fairspectrum has shown leadership in the area of geolocation database provider in Europe. Fairspectrum provided and provides the first commercial geolocation database for TV White Space in Europe. The Fairspectrum database service was specified and qualified by Ofcom, UK. Fairspectrum also developed and operates the 2.3 GHz wireless camera spectrum management system for the Radiocommunications Agency Netherlands. Fairspectrum has piloted CEPT and ETSI specified Licensed Shared Access system in Finland, and Italy. Fairspectrum has piloted and demonstrated CBRS functionalities in Finland and Poland. Fairspectrum won the Collaborative Spectrum Sharing Prize of the European Commission in 2016. Furthermore, Fairspectrum collaborates with the leading researchers and organizations in the area of Dynamic Spectrum Access. Fairspectrum is a member of Wireless Innovation Forum, 3GPP, and ETSI. Fairspectrum participates in Dynamic Spectrum Access research collaboration in Finnish national projects, European Commission funded projects, and 5G Public Private Partnership (5GPPP) spectrum committee.

Fairspectrum LLC is a Delaware registered company and 100 % owned by Fairspectrum Oy, a Finland company. Through Fairspectrum LLC, Fairspectrum will invest in SAS in the US and provide SAS technical and management resources. Fairspectrum LLC will carry out day-to-day functions and sales of the SAS Administrator in the US, supported by Fairspectrum Oy.

Release 1 of Wireless Innovation Forum (WINNF) Spectrum Sharing Committee is separated as one reference group. Release 1 will be used by the time of first certifications. At the time of this updated application on Mar 9, 2017, all Release 1 specifications are not available. The references to WINNF documents in this application are generally made to the latest publicly available document.

2015, and FCC 16-55 “Amendment of the Commission’s Rules with Regard to Commercial Operations in the 3550-3650 MHz Band,” GN Docket 12-354, FCC 16-55, Order on Reconsideration and Second Report and Order

The structure of this application document follows the list of information that is required by the SAS Administrator order in DA 15-1426[3]. Sections 1-8 respond to the information that is required for all applications: 1. Functions; 2 Expertise; 3. Financial; 4. Security; 5. Architecture; 6. Propagation model; 7 Software update; and 8 Affirmation to comply. Sections 9-18 respond to the information that is required for SAS proposals: 9 Information verification; 10 Interference resolving; 11 Interference protection methods; 12 SAS to SAS; 13 Other SAS entities; 14 Protocols; 15 Comply 96.55; 16 Access authorization; 17 Use-case scenarios; and 18 FCC interface. Section 19 contains a letter from a Fairspectrum Oy investor to confirm the financial capability for Fairspectrum to operate as a SAS Administrator. In the beginning of each section, there is a description of the information required by the SAS Administrator applications. Before the numbered content sections, this application also includes an introduction, table of contents, list of abbreviations, and references. The application contains references as footnotes and items on the list of references with the exception of Code of Federal Regulations, Title 47, Part 96, which are marked with style "§96.55" in the text and found as items in the list of references. The references are grouped as follows: Wireless Innovation Forum, Spectrum Sharing Committee (SSC), Release 1, Code of Federal Regulations, Code of Laws of the United States of America, Federal Communications Commission, National Telecommunications and Information Administration, IETF, ISO/IEC, and Other.

[3] DA 15-1426 FCC. Wireless Telecommunications Bureau and office of engineering and technology establish procedure and deadline for filing Spectrum Access System (SAS) administrator(s) and Environmental Sensing Capability (ESC) applications. December 16, 2015.

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Abbreviations

3GPP	3rd Generation Partnership Project
5GPPP	5G Infrastructure Public Private Partnership
BA	Bachelor of Arts
CALEA	Communications Assistance for Law Enforcement Act
CBRS	Citizens Broadband Radio Service
CBSD	Citizens Broadband radio Service Device
CEO	Chief Executive Officer
CEPT	European Conference of Postal and Telecommunications Administrations
C.F.R.	Code of Federal Regulations
CIO	Chief Information Officer
CIPP/US	Certified Information Privacy Professional/United States
CNPI	Customer Proprietary Network Information
CPI	Certified Professional Installer
CRL	Certification Revocation List
CTO	Chief Technology Officer
DB	DataBase
Dr	Doctor
DSA	Dynamic Spectrum Access
DSc	Doctor of Science
DySPAN	Dynamic Spectrum Access Networks
E911	Enhanced 911
EAS	Equipment Authorization System
EC	European Commission
EC R&I	EC Research & Innovation
EC2	Elastic Computing Cloud
eHata	extended Hata
en	English
ESC	Environmental Sensing Capability
ETSI	European Telecommunications Standards Institute
EZ	Exclusion Zone
FCC	Federal Communications Commission
FS	Fairspectrum
FSS	Fixed-Satellite Service
GAA	General Authorized Access
GESC	Gain of ESC sensor antenna
GWBL	Grandfathered Wireless Broadband Licensees
GWPZ	Grandfathered Wireless Protection Zones
HIPAA	Health Insurance Portability and Accountability Act
HITECH	Health Information Technology for Economic and Clinical Health

HUI	Human User Interface
IAPP	International Association of Privacy Professionals
IBFS	International Bureau Filing System
ID	Identifier
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISO	International Organization of Standardization
ITM	Irregular Terrain Model
ITS	Institute for Telecommunication Sciences
JD	Juris Doctor
JSON	JavaScript Object Notation
LLC	Limited Liability Company
LNP	Local Number Portability
LSA	Licensed Shared Access
LTE	Long Term Evolution
M2M	Machine-To-Machine
MA	Master of Arts, Massachusetts
MRLC	Multi-Resolution Land Characteristics Consortium
MSc	Master of Science
NACP	Native American Cancer Prevention
NLCD	National Land Cover Database
NTIA	National Telecommunications and Information Administration
OET	Office of Engineering and Technology
OpenSSRF	Open source Standard Spectrum Resource Format
Oy	Osakeyhtiö (Limited Liability Company)
UR-ID	User Registration ID
PAL	Priority Access License
PKI	Public Key Infrastructure
PPA	PAL Protection Area
PZ	Protection Zone
RDS	Relational Database Service
RFC	Request For Comments
RMS	Root Mean Square
RSA	Ron Rivest, Adi Shamir, Leonard Adleman (cryptographic algorithm)
SAS	Spectrum Access System
SES	Simple Email Service
SCP	Secure Copy Protocol
SFTP	Secure File Transfer Protocol
SSC	Spectrum Sharing Committee

SSH	Secure SHell
TLS	Transport Layer Security
TVWS	TeleVision White Space
UK	The United Kingdom
ULS	Universal Licensing System
US	The United States
U.S.C.	Code of Laws of the United States of America
USGS	United States Geological Survey
VoIP	Voice over IP
VPC	Virtual Private Cloud
WG	Working Group
WINNF	Wireless Innovation Forum
WTB	Wireless Telecommunications Bureau

References

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	-TS-0061-V1.1.0%20-%20WG4%20SAS%20Test%20and%20Certification%20Spec.pdf.
WINNF-TS-0122	V1.0.0 CBRS CBSD Test and Certification Specification. 19 December 2017. Available at https://workspace.winnforum.org/higherlogic/ws/public/download/4987/WINNF-TS-0122-V1.0.0%20CBRS%20CBSD%20Test%20Specification.pdf.
WINNF-TS-0245	Version 1.0.0. PAL Database. 26 July 2017. Available at https://workspace.winnforum.org/higherlogic/ws/public/download/4488/WINNF-TS-0245-V1.0.0%20PAL%20Database%20.pdf.
WINNF-TS-0022	Version 1.1.2. CBRS PKI Certificate Policy. 6 February 2018. Available at https://workspace.winnforum.org/higherlogic/ws/public/download/6020/WINNF-TS-0022%20v1.1.2%20CBRS%20PKI%20Certificate%20Policy.pdf.
WINNF-TS-0247	V1.0.0 CBRS Certified Professional Installer Accreditation. 18 October 2017. Available at https://workspace.winnforum.org/higherlogic/ws/public/download/4797/WINNF-TS-0247-V1.0.0%20CPI%20Accreditation%20Standard.pdf.

Code of Federal Regulations

Title 47	Code of Federal Regulations, Telecommunications, available at: www.ecfr.gov.
Title 47, Part 96	Citizens Broadband Radio Service. Available at http://www.ecfr.gov/cgi-bin/text-idx?node=pt47.5.96&rgn=div5.
47 C.F.R. § 1.9046	Special provisions related to spectrum manager leasing in the Citizens Broadband Radio Service.
47 C.F.R. § 2.106	Table of frequency allocations.
47 C.F.R. § 96.17	Protection of existing fixed satellite service (FSS) earth stations in the 3600-3700 MHz Band and 3700-4200 MHz Band.
47 C.F.R. § 96.1331	Restrictions on the operation of base and fixed stations.
47 C.F.R. § 96.25	Priority Access Licenses.
47 C.F.R. § 96.33	Authorization.
47 C.F.R. § 96.35	General authorized access use.
47 C.F.R. § 96.39	Citizens Broadband Radio Service Device (CBSD) general requirements.
47 C.F.R. § 96.41	General radio requirements.
47 C.F.R. § 96.43	Additional requirements for category A CBSDs.
47 C.F.R. § 96.45	Additional requirements for category B CBSDs.
47 C.F.R. § 96.49	Equipment authorization.
47 C.F.R.§ 96.53	Spectrum access system purposes and functionality.
47 C.F.R.§ 96.55	Information gathering and retention.
47 C.F.R § 96.57	Registration, authentication, and authorization of Citizens Broadband Radio Service Devices.
47 C.F.R. § 96.59	Frequency assignment.
47 C.F.R. § 96.61	Security.

47 C.F.R. § 96.63 Spectrum access system administrators.
47 C.F.R. § 96.65 Spectrum access system administrator fees.
47 C.F.R. § 96.66 Spectrum access system responsibilities related to priority access spectrum manager leases.

Code of Laws of the United States of America

47 U.S.C. 606 Title 47. Telegraphs, telephones, and radiotelegraphs. Chapter 5. Wire or radio communication. Subchapter VI. Miscellaneous provisions. Sec. 606. War powers of president.

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DA 17-339 FCC. Wireless Telecommunications Bureau and office of engineering and technology establish "second wave" deadline for proposals from prospective Spectrum Access System (SAS) administrator(s) and Environmental Sensing Capability (ESC) operator(s). April 7, 2017.

DA 15-1426 FCC. Wireless Telecommunications Bureau and office of engineering and technology establish procedure and deadline for filing Spectrum Access System (SAS) administrator(s) and Environmental Sensing Capability (ESC) applications. December 16, 2015.

FCC EAS FCC Equipment Authorization System. Available at https://www.fcc.gov/engineering-technology/laboratory-division/general/equipment-authorization.

FCC FSS 3.5 GHz Band - Protected Fixed Satellite Service(FSS) Earth Stations. Available at https://apps.fcc.gov/edocs_public/attachmatch/DOC-333151A1.xlsx.

FCC ULS FCC Universal Licensing System. Available at http://wireless.fcc.gov/uls/data/complete/l_micro.zip/.

National Telecommunications and Information Administration

NTIA 3550-3650. NTIA. Spectrum Management. 3550-3650 MHz. Available at https://www.ntia.doc.gov/category/3550-3650-mhz.

ITM NTIA – ITS Irregular Terrain Model (ITM) (Longley-Rice) (20MHz-20 GHz):

http://www.its.bldrdoc.gov/resources/radio-propagation-software/itm/itm.aspx

3.5 GHz EZ — NTIA. 3.5 GHz Exclusion Zone Analyses and Methodology Available at https://www.ntia.doc.gov/report/2015/35-ghz-exclusion-zone-analyses-and-methodology

IETF

RFC-5280. Internet X.509 Public Key Infrastructure Certificate and Certification Revocation List (CRL) Profile. Available at https://www.ietf.org/rfc/rfc5280.txt.

RFC-5246. The Transport Layer Security (TLS) Protocol Version 1.2. Available at https://www.ietf.org/rfc/rfc5246.txt.

RFC-7159. The JavaScript Object Notation (JSON) Data Interchange Format.

ISO/IEC

ISO/IEC 27001:2013(en) Information technology. Security techniques. Information security management systems. Requirements.

ISO/IEC 27002:2013(en) Information technology. Security techniques. Code of practice for information security controls.

Other

Ofcom — White Space Database Operators. Available at https://tvws-databases.ofcom.org.uk/

CEPT — LSA implementations. Available at http://www.cept.org/ecc/topics/lsa-implementation.

Fierce Wireless — Europe's first TV white space licensee to use Fairspectrum's database. Available at http://www.fiercewireless.com/tech/europe-s-first-tv-white-space-licensee-to-use-fairspectrum-s-database.

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David Gomez-Barquero	5G-Xcast Broadcast and Multicast Communication Enablers for the Fifth-Generation of Wireless Systems. EUCNC on Jun 14, 2017.
5G-PPP Spectrum	5G-PPP Work Groups. Spectrum. Available at https://5g-ppp.eu/5g-ppp-work-groups/.
EC R&I Horizon Prizes	Collaborative spectrum sharing - € 500 000. Winner: Distribute. Available at https://ec.europa.eu/research/horizonprize/index.cfm?prize=spectrum-sharing.
NLCD 2011	Multi-Resolution Land Characteristics Consortium (MRLC). National Land Cover Database (NLCD). Available at https://www.mrlc.gov/nlcd11_data.php.
USGS	United States Geological Survey. The National Map. 3DEP Products and Services. Available at https://nationalmap.gov/3dep_prodserv.html.
ITS	Institute for Telecommunication Sciences. Irregular Terrain Model (ITM) (Longley-Rice) (20 MHz - 20 GHz). Available at https://www.its.bldrdoc.gov/resources/radio-propagation-software/itm/itm.aspx.
Census Tract	United States. Census Bureau. Topologically Integrated Geographic Encoding and Referencing. https://www.census.gov/geo/maps-data/data/tiger.html
OpenSSRF	Open source Standard Spectrum Resource Format. See,http://openssrf.org/.

1 Functions

"A detailed description of the scope of the functions that the SAS and/or ESC would perform."

This section describes the Fairspectrum SAS functions. Fairspectrum SAS functions are:

1. Obtaining and storing data according to 47 C.F.R. § 96.55
2. Registering, authenticating, and authorizing of CBSDs according to 47 C.F.R § 96.57
3. Assigning frequencies according to 47 C.F.R. § 96.59
4. Securing communications according to 47 C.F.R. § 96.61
5. Providing functionality to administrate SAS according to 47 C.F.R. § 96.63
6. Billing and charging according to 47 C.F.R. § 96.65

1.1 Obtaining and storing data

Fairspectrum obtains and stores data according to Commission Rule §96.55. Fairspectrum collects the registration information by utilizing registration procedure of WINNF-TS-0016[4] or its latest version.

[4] WINNF-TS-0016 Version 1.2.1 SAS to CBSD Protocol Specification. 3 January 2018.

Fairspectrum keeps information on registered CBSDs according to Commission Rules §96.39, §96.43, and §96.45; geographic locations; protected Fixed Satellite Service (FSS) locations according to Rule §96.17; and, the Exclusion Zones and Protection Zones of the federal Incumbents.

Fairspectrum provides required CBSD coordination information to other SAS Administrators utilizing the protocol specified in WINNF-TS-0096 or its latest version. Fairspectrum provides CBSD registration information to general public so that identities are concealed. Fairspectrum stores the registration information and location of protected earth stations in database tables according to Rule §96.17. Fairspectrum stores the user transmission log files, excluding the federal users, for at least 60 months. Fairspectrum does not store federal Incumbent User information from ESC anymore than ESC approval policy dictates. Fairspectrum designs all required system integration work to interface with FCC databases. Fairspectrum collects acknowledgements from all CBSD registering entities that they understand risk of possible interference from federal Incumbent radar operating in the band.

1.2 Registering, authenticating, and authorizing

Fairspectrum registers, authenticates, and authorizes CBSDs. Before allowing an entity to register CBSDs, the entity needs to create a partnership with Fairspectrum. As part of the partnership, Fairspectrum or authorized CBRS certificate authority provide the partner with credentials, which are required to register CBSDs. The CBSD registration is carried out with Registration procedure of WINNF-TS-0016 or its latest version. Authentication is carried out with Authentication procedure of WINNF-TS-0016 or its latest version. The mutual authentication is based on Public Key Infrastructure and certificates (RFC-5280[5]) on TLS-v1.2 (RFC-5246[6]) following the WINNF-TS-0022[7] certificate policy. The authentication follows the guidelines set in WINNF-TS-0065[8] or its latest version. For all FCC Identifiers intending to register, Fairspectrum checks the validity of the ID from the Commission's

[5] RFC-5280. Internet X.509 Public Key Infrastructure Certificate and Certification Revocation List (CRL) Profile. Available at https://www.ietf.org/rfc/rfc5280.txt.
[6] RFC-5246. The Transport Layer Security (TLS) Protocol Version 1.2. Available at https://www.ietf.org/rfc/rfc5246.txt.
[7] WINNF-TS-0022 Version 1.1.2. CBRS PKI Certificate Policy. 6 February 2018..
[8] WINNF-TS-0065 Version 1.1.0. 26 July 2017. CBRS Communications Security

Equipment Authorization System.[9] Only registered and authenticated CBSDs are authorized to use the Fairspectrum SAS service. When federal incumbents are protected with Protection Zones, Fairspectrum only authorizes CBSDs within the Protection Zones based on ESC information according to §96.67. Fairspectrum computes and utilizes PAL Protection Areas according to §96.25 and relevant WINNF specifications.

A Domain Proxy may represent a number of CBSDs according to WINNF-TS-0016[10] or its latest version. When Domain Proxy represents a number of CBSDs, TLS mutual authentication is carried out between the SAS and the Domain Proxy. A successful authentication is prerequisite for all SAS-CBSD and SAS - Domain Proxy procedures. If there is a Domain Proxy and the Domain Proxy is performing bulk CBSD registration, the Domain Proxy aggregates registration information for multiple CBSDs. The Domain Proxy sends an array of RegistrationRequest objects to the SAS which represents the aggregated CBSD registration information. Upon reception of the array of RegistrationRequest objects, the SAS initiates registration for each CBSD. The SAS responds with an array of RegistrationResponse objects, each containing a registration response to a CBSD. A Domain Proxy correlates the response objects with request objects using the JSON array object order. JSON arrays are ordered sequences; as such, a multiple request message or multiple response message contains an ordered sequence of objects. Domain Proxies, SASs and CBSDs preserve array ordering. SASs receiving a message having an array of request objects shall response with an array of response objects in which the order of the response objects is exactly matched to the order of the request objects.

1.3 Assigning frequencies

Fairspectrum determines the available and suitable frequency ranges for CBSDs by utilizing a combination of Registration, Spectrum Inquiry, Grant, and Heartbeat procedures of WINNF-TS-0016[9] or its latest version. In the Registration procedure, CBSD delivers its location and configuration. In Spectrum Inquiry, CBSD optionally requests the range of available operation parameters. In Grant,

[9] FCC EAS FCC Equipment Authorization System. Available at https://www.fcc.gov/engineering-technology/laboratory-division/general/equipment-authorization.
[10] WINNF-TS-0016 Version 1.2.1 SAS to CBSD Protocol Specification. 3 January 2018.

CBSD requests a specific set of operational parameter to be used. In Heartbeat, a successful Grant is authorized and the authorization is maintained. Heartbeat procedure is maintained during the transmission of CBSD. Any changes in protection, which limit the availability of the CBSD grant, are signalled from SAS to CBSD with Heartbeat Response. When determining the available and suitable frequency ranges, SAS takes into account, for example, CBSD location, authorization status, operating parameters of other CBSDs, information from ESC and other SASs. Fairspectrum carries out the assignments in a non-discriminatory manner. Fairspectrum responds with the availability of the channels both to CBSD and FCC requests. Fairspectrum provides an interface for FCC to check the assignments. Fairspectrum authorizes 10 MHz channels for PAL use in frequency band 3550-3650 MHz up to a total of seven channels, and assigns the same frequency range for PALs in contiguous geographical areas where possible. Similarly, when a PAL has several frequency blocks in a geographical area, Fairspectrum assigns those frequency blocks contiguously when possible. Temporarily, non-contiguous channels may be assigned to individual PALs whenever needed to protect Incumbent Users. When incumbent protection requires, Fairspectrum changes PAL assignments or ends PAL assignments. For GAA use, Fairspectrum may assign channels in the frequency band 3550-3700 MHz band according to §96.35. PAL channels in 3550-3650 MHz band shall be made available only in areas outside the PAL Protection Area, consistent with §96.25 and §96.41(d). Chapter 11 provides detailed information about the protection methods.

When SAS sends the available frequencies and other operating parameters to CBSD in spectrumInquiryResponse message, CBSD has to confirm the willingness to use a specific set of operating parameters, including the frequency range in GrantRequest message according to § 96.59. spectrumInquiryRequest contains a field inquiredSpectrum, which describes the spectrum for which the CBSD seeks information on spectrum availability. spectrumInquiryResponse contains a field availableChannel, which is an array describing the channels that are available for the CBSD. After receiving the spectrumInquiryResponse, CBSD has to send a grantRequest message. The message contains operationFrequencyRange describing a contiguous frequency subset of from the

availableChannel field in the received spectrumInquiryResponse. Before being allowed to transmit, CBSD has to carry out a successful heartbeat procedure for the specific grant.

1.4 Securing communications

Fairspectrum follows the security recommendations in WINNF-TS-0065[11] or its latest version and WINNF-TS-0071[12] or its latest version. Authentication is carried out with Authentication procedure in WINNF-TS-0016[13] or its latest version. The mutual authentication is based on Public Key Infrastructure and certificates (RFC-5280[14]) on TLS-v1.2 (RFC-5246[15]) and takes into account certificate recommendations in WINNF-TS-0022[16]. The communication between the Fairspectrum SAS and any other entity, including a CBSD, Domain Proxy, another SAS, and ESC, and all user interfaces is encrypted using TLS ciphersuites. The access to management interfaces is authenticated and authorized. Each user type has different authorization levels allowing access to respective information and capabilities. On organizational level, Fairspectrum applies Information Security controls of ISO/IEC 27001:2013(en)[17] and ISO/IEC 27002:2013(en).[18] For all FCC Identifiers intending to register, Fairspectrum checks the validity of the ID from the Commission's Equipment Authorization System[19] and uses that information in authorization.

1.5 Providing functionality to administrate SAS

Fairspectrum maintains a database service and updates it regularly. The Fairspectrum server system contains a client, which checks and downloads the PAL assignments, new radio licenses, and changes in the existing licenses from FCC databases. Fairspectrum has administrative and technical personnel

[11] WINNF-TS-0065 Version 1.1.0. 26 July 2017. CBRS Communications Security Technical Specification..
[12] WINNF-TS-0071 Version 1.0.0. 26 July 2017. CBRS Operational Security Technical Specification.
[13] WINNF-TS-0016 Version 1.2.1 SAS to CBSD Protocol Specification.
[14] RFC-5280. Internet X.509 Public Key Infrastructure Certificate and Certification Revocation List (CRL) Profile. Available at https://www.ietf.org/rfc/rfc5280.txt.
[15] RFC-5246. The Transport Layer Security (TLS) Protocol Version 1.2. Available at https://www.ietf.org/rfc/rfc5246.txt.
[16] WINNF-TS-0245 Version 1.0.0. PAL Database. 26 July 2017.
[17] ISO/IEC 27001:2013(en) Information technology. Security techniques. Information security management systems. Requirements.
[18] ISO/IEC 27002:2013(en) Information technology. Security techniques. Code of practice for information security controls.
[19] FCC EAS FCC Equipment Authorization System. Available at https://www.fcc.gov/engineering-technology/laboratory-division/general/equipment-authorization.

to ensure that any FCC request related to the SAS service is fulfilled in a shortest possible time. Fairspectrum follows the security guidelines of WINNF-TS-0065[10] or its latest version and WINNF-TS-0071[20] or its latest version, implements automated checks for input values, and carries out human checks on data and results. Fairspectrum is ready to provide the service in 5-year terms, when approved by FCC. Fairspectrum logs all access to and use of SAS in a format which can with a reasonable effort be transferred to another database platform. Fairspectrum supports WINNF-TS-0096 [21] or its latest version and ensures that the required business processes are in place for SAS-to-SAS communication. Fairspectrum SAS service contains a web user interface including a map functionality, which can be used to provide non-federal, non-proprietary information to general public, among other things. Fairspectrum provides FCC with both machine-to-machine and human user interface to verify various functionalities of the SAS service. Fairspectrum establishes and follows protocols to respond to instructions from FCC, the President of the United States, or another designated Federal government entity, issued pursuant to 47 U.S.C. 606[22].

Fairspectrum SAS will be technically capable of directly interfacing with any necessary FCC database containing information required for the proper operation of an SAS according to § 96.55. Fairspectrum SAS server processing environment has a software client, e.g. https client, ftps client, or scp client, which is configured with the selected authentication credentials, like shared secret, client certificate, or user name and password. The FCC database access client software has a timing mechanism implemented either in the client software itself or in the operating system e.g. as cron task. The timing mechanism is scheduled to synchronize with the FCC databases at least once a day. The FCC database access client software downloads the new files from the FCC database. It carries out a necessary amount of consistency checks about the data. If there are inconsistencies, the synchronization process is aborted and the system administrator is alerted to study the issues. Otherwise, the data on the SAS server is synchronized with the FCC database downloaded data. Depending on the type of data, pre-processing

[20] WINNF-TS-0071 Version 1.0.0. 26 July 2017. CBRS Operational Security Technical Specification.
[21] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.
[22] 47 U.S.C. 606 Title 47. Telegraphs, telephones, and radiotelegraphs. Chapter 5. Wire or radio communication. Subchapter VI. Miscellaneous provisions. Sec. 606. War powers of president.

of the data may be carried out before it is taken into account in the SAS-CBSD communication. Regular backups are created also for the FCC data on the Fairspectrum SAS server, so that the previous version of the data can be restored in the case of errors. The Fairspectrum SAS filesystem is encrypted. The servers and data storages are located on Amazon AWS (or alternatively on Microsoft Azure) cloud service in the US. The data is stored as original files in the filesystem, in tables in the database, and in backup files. Temporarily, small and specific parts of the data may be stored for debugging, error solving, or development purposes on the hard disks of the developers and system administrators.

Fairspectrum SAS operates without any connectivity to any military or other sensitive federal database or system, except as otherwise required by this part; and it does not store, retain, transmit, or disclose operational information on the movement or position of any federal system or any information that reveals other operational information of any federal system that is not required by this part to effectively operate the SAS.

1.6 Billing and charging

Fairspectrum will implement a billing and charging system, which is primarily linked to authentication and authorization so that the customer agreements and related payments authorize the CBSDs of the customer to access Fairspectrum service for a month or a year. Additionally, Fairspectrum considers to implement a pay-per-use billing system, which could record and invoice the use per request, hour, or day basis. The fees of Fairspectrum are set so that whatever radio communication business the service enables, the service fee is reasonable for that purpose. Fairspectrum provides information about the service fees to FCC and, upon FCC request, is ready to adjust them.

1.7 PAL leasing

Fairspectrum will accept leasing notifications fulfilling the rules set in C.F.R. § 96.66. Fairspectrum verifies that the lessee is on the certification list as required in § 1.9046. Fairspectrum establishes a process for acquiring and storing the lease notification information and synchronizing this information, including information about the expiration, extension, or termination of leasing arrangements, with the Commission databases at least once a day. Fairspectrum verifies that the lease will not result in the

lessee holding more than the 40 megahertz of Priority Access spectrum in a given License Area. Fairspectrum verifies that the area to be leased is within the Priority Access Licensee's Service Area and outside of the Priority Access Licensee's PAL Protection Area. Fairspectrum provides confirmation to licensee and lessee whether the notification has been received and verified. During the period of the lease and within the geographic area of a lease, Fairspectrum shall treat any CBSD operated by the lessee the same as a similarly situated CBSDs operated by the lessor for frequency assignment and interference mitigation purposes.

2 Expertise

"A demonstration that the prospective SAS Administrator or ESC operator possesses sufficient technical expertise to operate an SAS and/or ESC, including the qualifications of key personnel who will be responsible for operating and maintaining the SAS and/or ESC."

Fairspectrum has a substantial experience in researching, developing, operating, and maintaining Dynamic Spectrum Access database services, like TV White Space (TVWS), Licensed Shared Access (LSA), and Citizen's Broadband Radio Service (CBRS). Fairspectrum provides commercial TV White Space (TVWS) geolocation database service in the United Kingdom[23] and pre-Licensed Shared Access (LSA) spectrum coordination service for 2.3 GHz wireless cameras in the Netherlands[24]. Fairspectrum has participated in (TVWS) pilots in Finland[25] and in the UK[26] in LSA pilots in Italy[27], in Finland[28], in CBRS pilots in Finland,[29] and in Poland.[30] Fairspectrum contributes to 5G spectrum sharing in an

[23] Ofcom. White Space Database Operators. Available at https://tvws-databases.ofcom.org.uk/.
[24] CEPT. LSA implementations. Available at http://www.cept.org/ecc/topics/lsa-implementation.
[25] Fierce Wireless. Europe's first TV white space licensee to use Fairspectrum's database. Available at http://www.fiercewireless.com/tech/europe-s-first-tv-white-space-licensee-to-use-fairspectrum-s-database.
[26] Center for White Space Communications. Glasgow Pilot Launch Event. Available at http://www.wirelesswhitespace.org/projects/white-space-pilot-network-in-glasgow-phase-1/glasgow-pilot-launch-event/.
[27] Guiducci, Doriana, et al. Sharing under licensed shared access in a live LTE network in the 2.3–2.4 GHz band end-to-end architecture and compliance results. Dynamic Spectrum Access Networks (DySPAN), 2017 IEEE International Symposium on. IEEE, 2017.
[28] M. Palola et al., Live field trial of Licensed Shared Access (LSA) concept using LTE network in 2.3 GHz band, 2014 IEEE International Symposium on Dynamic Spectrum Access Networks (DYSPAN), McLean, VA, 2014, pp. 38-47. doi: 10.1109/DySPAN.2014.6817778.
[29] WINNF Europe. Citizen's Broadband Radio Service enables micro-operators to provide Industrial automation. Available at http://www.europe.wirelessinnovation.org/2017-showcase-demonstrations.

European Commission (EC) Horizon 2020 project called Coherent,[31] 5G-XCAST,[32] and in the 5G Public Private Partnership (5G-PPP) spectrum group.[33] Fairspectrum won the collaborative spectrum sharing award of the EC in the end of 2016.[34] Fairspectrum is a member of ETSI, 3GPP, and Wireless Innovation Forum. In these activities, Fairspectrum has gained a substantial understanding of Dynamic Spectrum Access (DSA) in Europe.

2.1 Key personnel

Dr. Heikki Kokkinen is the CEO and founder of Fairspectrum LLC and Fairspectrum Oy. Heikki holds a doctoral degree in Computer Science, an academic entrepreneur degree from Aalto School of Business, licentiate degree in telecommunications and industrial economics, and Master's degree in electronics. Heikki is devoted to marketing, research and development, financing, system integration, piloting and deploying of spectrum sharing technologies. Heikki has been the project manager, system architect, and system administrator in all Fairspectrum activities in the past. He has implemented protocol and database interfaces in most Fairspectrum systems.

Mr. Franklin Reynolds is the CTO of Fairspectrum LLC. Franklin has over 30 years of experience as a contributor and a leader of Research and Development teams, including 6 years at the Open Software Foundation Research Institute where he worked on distributed operating systems and 11 years at Nokia Research where most of his work was on self-organizing distributed systems. His current interests include the development and operation of scalable, highly available distributed systems. He has written papers and articles on smartphones, secure distributed systems, and free software. He has five software patents.

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[30] Heikki Kokkinen. Europe moves towards Dynamic Spectrum Access. Keynote at WinnComm Europe on May 18, 2017. See http://www.europe.wirelessinnovation.org/2017-presentation-abstracts.
[31] 5G-PPP Coherent. Coherent. Coordinated control and spectrum management for 5G heterogeneous radio access networks. Available at https://5g-ppp.eu/coherent/.
[32] David Gomez-Barquero. 5G-Xcast Broadcast and Multicast Communication Enablers for the Fifth-Generation of Wireless Systems. EUCNC on Jun 14, 2017.
[33] 5G-PPP Spectrum. 5G-PPP Work Groups. Spectrum. Available at https://5g-ppp.eu/5g-ppp-work-groups/.
[34] EC R&I Horizon Prizes. Collaborative spectrum sharing - € 500 000. Winner: Distribute. Available at https://ec.europa.eu/research/horizonprize/index.cfm?prize=spectrum-sharing.

Mr. Jaakko Ojaniemi is the CTO of Fairspectrum Oy. Jaakko will complete his Doctoral degree in 2018. Jaakko has designed and implemented radio computational algorithms to Fairspectrum database, providing dynamic spectrum access for TVWS (470-698 MHz), LSA 2.3 GHz and 700 MHz, and CBRS 3.5 GHz bands. At Aalto University he has developed algorithms and methods for modeling signal propagation based on prediction models and field measurements. He has developed simulation environment for analyzing the operation of large-scale cognitive radio network.

Mr. Arto Kivinen is the CIO of Fairspectrum. Arto has BSc in Computer Science. Arto has maintained the development and server environment in all Fairspectrum server systems. He has developed protocol and user interfaces for incumbents, operators, regulators, and system administrators in TVWS, LSA, and CBRS Dynamic Spectrum Access systems.

Mr. Barlow Keener is the counsel for Fairspectrum LLC and Fairspectrum Oy in CBRS matters. Barlow Keener specializes in privacy, spectrum, Internet, and telecommunications law and regulation. Barlow is a privacy and cybersecurity law attorney and earned a CIPP/US privacy law certification, or "Certified Information Privacy Professional", from the IAPP (International Association of Privacy Professionals). He manages issues related to startup firms including incorporation, general corporate governance, and intellectual property. He provides counsel for intellectual property transactions in software, hardware, and technology consulting. Barlow represents Internet providers, both wired and wireless, in state and FCC regulatory matters. He has also provided counsel and consulting for VoIP and telecom startups and for state governments. He has worked on issues involving TV White Spaces, spectrum sharing, E911, CNPI, CALEA, NANP, VoIP, and LNP.. He has bar admissions in Florida, Georgia, and Massachusetts. Education: JD, Emory University School of Law; MA, History, North Carolina Central University; BA, History, University of the South - Sewanee; CIPP/US Privacy certification, IAPP.

Prof. Risto Wichman is Fairspectrum board member and technical advisor. Risto Wichman received his M.Sc. and D.Sc. (Tech.) degrees in digital signal processing from Tampere University of Technology, Tampere, Finland, in 1990 and 1995, respectively. From 1995 to 2001, he worked at Nokia Research Center as a senior research engineer. In 2002, he joined Department of Signal Processing and Acoustics, Aalto University School of Electrical Engineering, Finland, where he has been a full professor since 2008. His research interests include signal processing techniques for wireless communication systems.

3 Financial

"The prospective SAS Administrator or ESC operator must demonstrate that it is financially capable of operating an SAS and/or ESC for a five year term. The proposal must include a description of the prospective SAS Administrator or ESC operator's business structure including ownership information. To the extent that the proponent will rely on fees to support its operations, the proposal should also describe the fee collection process and the entities from which the fees will be collected."

Business structure: Fairspectrum LLC[35] is a Delaware limited liability company founded in 2017 and is a wholly owned subsidiary of Fairspectrum Oy.[36] Fairspectrum Oy is a Finnish limited liability company that has been operating since 2010 with its business solely focused on providing database services for spectrum. Fairspectrum Oy is 90% owned by employees and founders in Finland and 10% owned by communications investor G.I.T. Telecom.[37] Fairspectrum LLC will employ sales managers and database technicians to manage and service all US SAS operations.

Financial capability: Fairspectrum is financially capable of passing through the certification process and operating SAS for a five year term. Since 2011, Fairspectrum has received public funding for spectrum database development and services from European Commission Research and Innovation,[38]

[35] Fairspectrum LLC is registered with the Delaware Division of Corporations.
[36] The Business Information System of Finland. Tradename: Fairspectrum.
[37] Department of registrar of companies and official receiver of Cyprus. Name: G.I.T. Telecom.
[38] http://ec.europa.eu/research/index.cfm

TEKES - Finnish Funding Agency for Innovation,[39] and Ministry for Foreign Affairs for Finland.[40] In 2016, Fairspectrum won the 2016 Horizon Prize from the European Commission for "Collaborative Spectrum Sharing".[41] Moreover, from 2011, Fairspectrum has participated in customer and collaboration agreements for dynamic spectrum sharing projects with Telecom Italia, BT (UK), European Broadcasting Union (Switzerland), BBC (UK), Poste Mobile (Italy), Telia (Finland), Digita (Finland), Elisa (Finland), DNA (Finland), INEA (Poland), OTE (Greece), and Finnet (Finland). Also, from 2011 through 2017, Fairspectrum has conducted spectrum sharing projects for numerous manufacturers of communications equipment including: Nokia (Finland); Bittium (Finland); BAE Systems (UK); Teleste (Finland); Airbus (France); Thales Communications and Security (France); ST Microelectronics (Finland); Samsung Electronics (UK); Qualcomm (Italy); and Ericsson (Finland); Carlson Wireless (US); and 6Harmonics (Canada).

In addition, Fairspectrum has participated as a spectrum sharing database manager through grants and research projects with many universities and research institutes including: Technical Research Center of Finland, Turku University of Applied Sciences (Finland); Aalto University (Finland); University of Turku (Finland), Oulu University (Finland); Centria University of Applied Sciences (Finland); Turku University of Applied Sciences (Finland); Eurecom (France); European Center for Information and Communication Technologies (Germany); University of Duisburg-Essen (Germany); Technical University of Berlin (Germany); University of Poznan (Poland), University of Strathclyde (Scotland); King's College London (UK); Queen Mary University of London (UK); Polytechnic University of Valencia (Spain), IRT (Germany); University of Surrey (UK); and FUB (Italy).

Fairspectrum has worked with many governmental agencies including: Ofcom (UK), Radiocommunications Agency of Netherlands; FICORA (Finnish Communications Regulatory

[39] https://www.tekes.fi/en/
[40] http://formin.finland.fi/public/default.aspx?culture=en-US&contentlan=2
[41] EC R&I Horizon Prizes. Collaborative spectrum sharing - € 500 000. Winner: Distribute. Available at https://ec.europa.eu/research/horizonprize/index.cfm?prize=spectrum-sharing.

Authority); Joint Research Center of European Commission (Italy); Finnish Defense Forces; Helsinki Region Transport (Finland); City of Jyväskylä (Finland); Ministry of Traffic and Communications of Finland; and, the Ministry of Economic Development of Italy.

As a result of the projects and partnerships listed above, Fairspectrum Oy operates with a profit. Fairspectrum Oy will use its financial resources to invest in Fairspectrum LLC for the US SAS business. Fairspectrum Oy will be able to fund Fairspectrum LLC, through direct investment, for SAS development, for the FCC certification and testing process, and for the first five years of Fairspectrum LLC's operation.

Fee collection: Fairspectrum LLC will sell its FCC approved SAS services to both network operators and manufacturers. Fairspectrum has designed a billing and charging system it will use to collect fee revenues from customers. The billing system is linked to the customer's CBSD authentication and authorization data, so that the customer agreements and related payments will approve the customer's CBDS access to Fairspectrum's service for a period of time tied to the billing agreement. Additionally, Fairspectrum may also implement a pay-per-use billing system, which could record and invoice the CBDS spectrum use on a per request, per hour, or per day basis. The fees of Fairspectrum are set so that whatever radio communication business the service enables, the Fairspectrum service fee is reasonable for that purpose. Fairspectrum will provide information about the service fees to FCC, upon FCC request, and is prepared to adjust the fees if so directed.

In addition to future revenues from Fairspectrum LLC's SAS services in the US and to the committed long-term investment by Fairspectrum Oy for Fairspectrum LLC's FCC approved SAS operations, Fairspectrum Oy's major communications investor is committed to supporting Fairspectrum's FCC certified SAS operations. A letter is appended to section 19 of this application from the investor confirming the commitment to financially support Fairspectrum's SAS service operation in the U.S.[42]

[42] *See* G.I.T. Telecom letter, appended hereto in Section 19.

4 Security

"A description of how data will be securely communicated between the SAS and its associated ESC and how quickly and reliably these communications will be accomplished."

Fairspectrum follows the security guidelines of WINNF-TS-0065[43] or its latest version and WINNF-TS-0071[44] or its latest version. WINNF-TS-0065[39] contains regulatory requirements, threat model, and operational security requirements. The operational security requirements are further divided into ESC requirements, Protection Zone activation, Exclusion/Protection Zone activation obfuscation, authorization limiting, obfuscating incumbent episodes, public release of CBSD registration information, and Channel availability lists - Incumbent frequency obfuscation. Fairspectrum IT security controls are based on ISO/IEC 27001:2013(en)[45] and ISO/IEC 27002:2013(en).[46] Fairspectrum deploys SAS-ESC communication security in the same way as SAS-SAS communication. The authentication is mutual PKI certificate authentication using TLS-V1.2 (RFC-5246)[47] and certificate chain takes into account WINNF-TS-0022.[48] The communication is encrypted and the used ciphersuite is one from the list of WINNF-TS-0096[49] or its latest version, for example TLS_RSA_WITH_AES_128_GCM_SHA256. Both SAS and ESC validate certificates according to RFC-5280.[50]

5 Architecture

"Technical diagrams showing the architecture of the SAS and/or ESC and a detailed description of how each function operates and how each function interacts with the other functions."

[43] WINNF-TS-0065 Version 1.1.0. 26 July 2017. CBRS Communications Security Technical Specification..
[44] WINNF-TS-0071 Version 1.0.0. 26 July 2017. CBRS Operational Security Technical Specification.
[45] ISO/IEC 27001:2013(en) Information technology. Security techniques. Information security management systems. Requirements.
[46] ISO/IEC 27002:2013(en) Information technology. Security techniques. Code of practice for information security controls.
[47] RFC-5246. The Transport Layer Security (TLS) Protocol Version 1.2. Available at https://www.ietf.org/rfc/rfc5246.txt.
[48] WINNF-TS-0022 Version 1.1.2. CBRS PKI Certificate Policy. 6 February 2018.
[49] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.
[50] RFC-5280. Internet X.509 Public Key Infrastructure Certificate and Certification Revocation List (CRL) Profile. Available at https://www.ietf.org/rfc/rfc5280.txt.

5.1 CBRS architecture

The Fairspectrum SAS system is fully compatible with the Wireless Innovation Forum SAS Functional architecture of WINNF-15-P-0047[51] or its latest version and shown in Figure 5.1. SAS has SAS-CBSD interface to CBSD or CBSDs represented by Domain Proxy according to WINNF-TS-0016[52] or its latest version. The procedures available for the interface include: registration, deregistration, spectrumInquiry, grant, heartbeat, and relinquishment. SAS has SAS-to-SAS interface to other SASs according to WINNF-TS-0096[53] or its latest version. The functionality of SAS-SAS interface includes: security, record exchange, and synchronization.

The Fairspectrum SAS interfaces with several external databases to acquire the necessary data for SAS. The data is parsed and stored in Fairspectrum SAS database in order to perform computations relevant to the operation of the CBRS system. The data consists of FCC data needed to protect the FSS stations and Grandfathered Wireless Broadband Licensees (GWBL), geographical data relevant for calculating PPAs and Grandfathered Wireless Protection Zones (GWPZ), exclusion zones (EZ) and protection zones (PZ) for protection of federal Incumbent Users, census tracts for PAL management, and US country borders for cross-border interference management.

The FSS data is obtained from the FCC site[54] as specified in WINNF-TS-0112. The GWBL data is stored in FCC Universal Licensing System (ULS)[55] and updated weekly along with the daily transaction files. Fairspectrum SAS synchronizes to these databases as necessary to maintain up to date information of the incumbent use. The geographical data consists of land cover data obtained from National Land Cover Database (NLCD)[56] and from terrain data obtained from United States Geological

[51] WINNF-15-P-0047 Version V1.0.0. 7 September 2015. SAS Functional Architecture.
[52] WINNF-TS-0016 Version 1.2.1 SAS to CBSD Protocol Specification. 3 January 2018.
[53] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017..
[54] FCC FSS 3.5 GHz Band - Protected Fixed Satellite Service(FSS) Earth Stations. Available at https://apps.fcc.gov/edocs_public/attachmatch/DOC-333151A1.xlsx.
[55] FCC Universal Licensing System. Available at http://wireless.fcc.gov/uls/data/complete/l_micro.zip/.
[56] NLCD 2011. Multi-Resolution Land Characteristics Consortium (MRLC). National Land Cover Database (NLCD). Available at https://www.mrlc.gov/nlcd11_data.php.

Survey's site,[57] both with an intrinsic angular resolution of 1 arc second. Higher resolution data may be used if required. Fairspectrum uses this geographical data to build a topographic database to be used in the propagation calculations.

The exclusion zones are specified for protection of federal incumbent use by NTIA[58] consisting of zones along the US coastline and around federal radiolocation sites in Keyhole Markup Language (KML) format. The EZs shall be updated when NTIA notifies the FCC as stated in WINNF-TS-0112.[59] Fairspectrum will keep an up to date record of the EZs in the SAS. The exclusion zones are maintained until one or more ESC are approved and used by at least one SAS, thereafter the EZs are converted to protection zones. The information about the census tract boundaries is used in managing the PAL assignments, where each PAL consists of a single census tract. These boundaries are obtained from the US Census Bureau[60] and stored in the Fairspectrum SAS as geographical objects. To account for international protection arrangements, Fairspectrum will use the boundaries of the United States with Canada[61] and Mexico[62] and store this information to the database. In accordance with §90.1337, the Fairspectrum SAS will not authorize the CBSD transmissions for category B devices within 8 km of the borders if its antenna direction is only within the 160-degree sector oriented away from the closest point on the border, nor within 56 km of the borders if its antenna direction is within the 200-degree sector oriented towards the closest point on the border. Category A CBSDs may not operate within 8 km of the closest point in the borderline.

In addition to the above described use of various datasets, Fairspectrum will use FCC's Equipment Authorization System (EAS) to validate that the CBSD making the request is registered in the FCC

[57] USGS. United States Geological Survey. The National Map. 3DEP Products and Services. Available at https://nationalmap.gov/3dep_prodserv.html.
[58] NTIA 3550-3650. NTIA. Spectrum Management. 3550-3650 MHz. Available at https://www.ntia.doc.gov/category/3550-3650-mhz
[59] WINNF-TS-0112 V1.4.1 CBRS Operational and Functional Requirements. Working Document.16 January 2018.
[60] United States. Census Bureau. Topologically Integrated Geographic Encoding and Referencing. https://www.census.gov/geo/maps-data/data/tiger.html
[61] US-Canada border. Available at https://transition.fcc.gov/oet/info/maps/uscabdry/uscabdry.zip
[62] US-Mexico border. Available at http://www.ibwc.gov/GIS_Maps/downloads/us_mex_boundary.zip

database, that is, the FCC ID provided by the CBSD is found from the list of valid devices retrieved from EAS.[63]

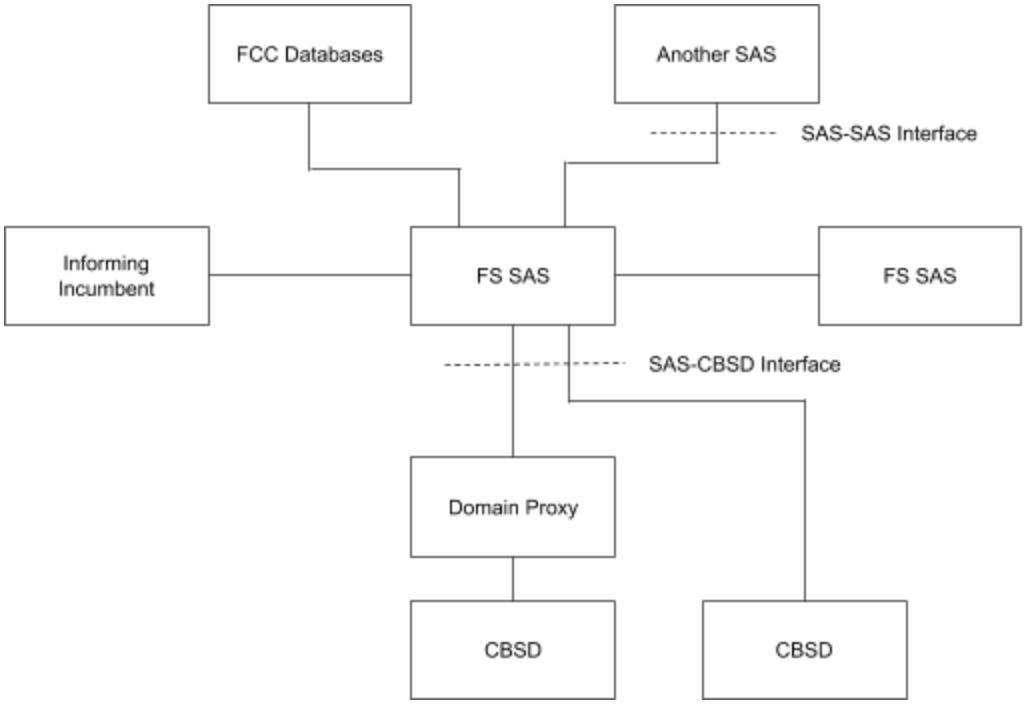

Figure 5.1 CBRS SAS functional architecture from WINNF-15-P-0047[64]

5.2 SAS interface architecture

Fairspectrum SAS has in practise more interfaces than WINNF-15-P-0047[57] specifies. The SAS interfaces are shown in Figure 5.2. FCC-SAS interface is both Machine-to-Machine (M2M) and Human User Interface (HUI). Topography and other geometry related interface is M2M. CBSD or Domain Proxy interface is M2M. Operator interface is both M2M and HUI. SAS-SAS interface is

[63] FCC EAS. Available at https://www.fcc.gov/engineering-technology/laboratory-division/general/equipment-authorization
[64] WINNF-15-P-0047 Version V1.0.0. 7 September 2015. SAS Functional Architecture.

M2M. System administrator interface is M2M and HUI. Informing incumbent interface is both M2M and HUI. General public has a web interface.

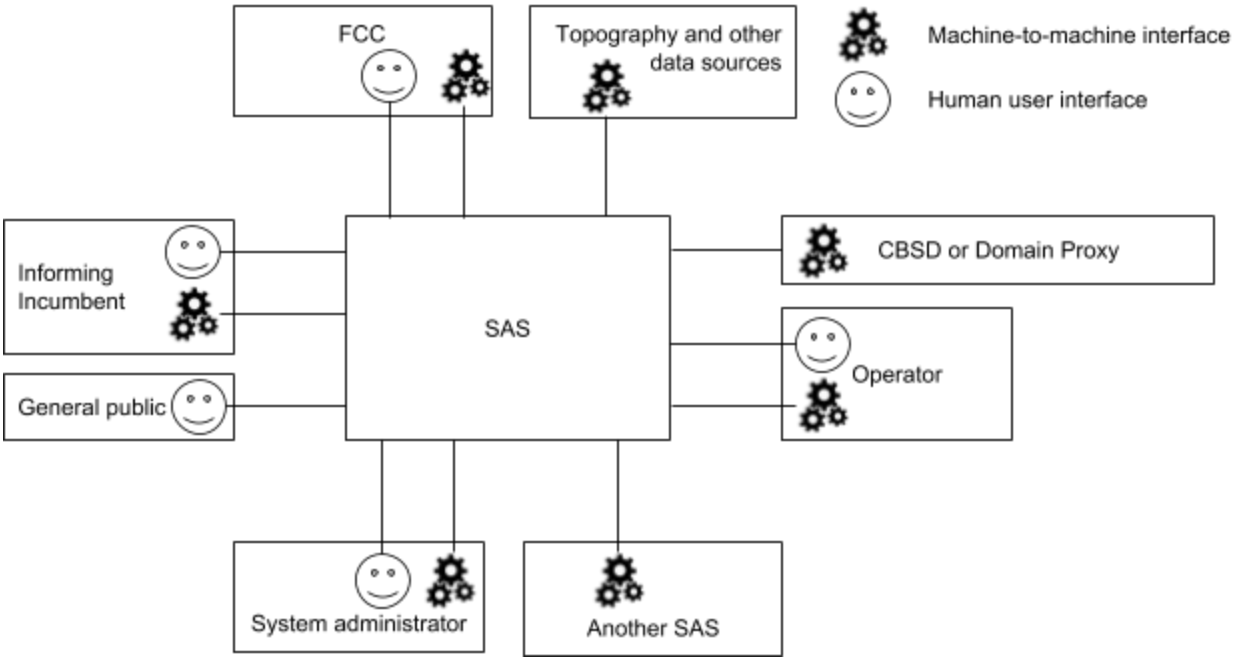

Figure 5.2 Fairspectrum SAS interfaces

5.3 Fairspectrum cloud server architecture

Fairspectrum SAS service is deployed in Amazon Elastic Computing Cloud (EC2) Virtual Private Cloud (VPC) servers (or alternatively in Microsoft Azure) in the US. The server architecture follows perimetry security model, see Figure 5.3. The requests from public Internet come to Load balancer, which is open for All. The SAS service runs in Application servers, which can only be accessed with http from the Load balancer. The database itself runs in Amazon Relational Database Service (RDS) database instance, which is only accessible from the Application servers. If the service requires emails to be sent, Fairspectrum SAS sends them using Amazon Simple Email Service (SES).

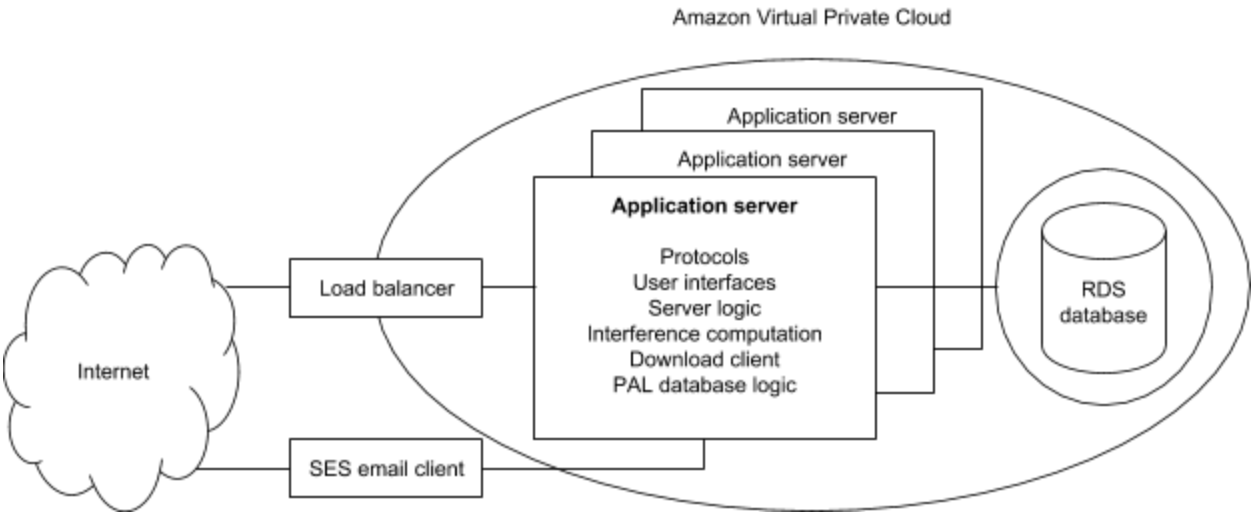

Figure 5.3 Fairspectrum Cloud server architecture

5.4 Mapping of SAS functions to Fairspectrum Application

Fairspectrum SAS application contains both server and client functionality from Internet communication perspective as shown in Figure 5.4. SAS server has both machine-to-machine and human user interfaces. Both client and server applications can access database. Obtaining and storing data function operates both as a server and client. Registering, authenticating, and authorizing of CBSDs is a server application, like assigning frequencies. Communications are secured both for server and client applications. Billing and charging is a server application.

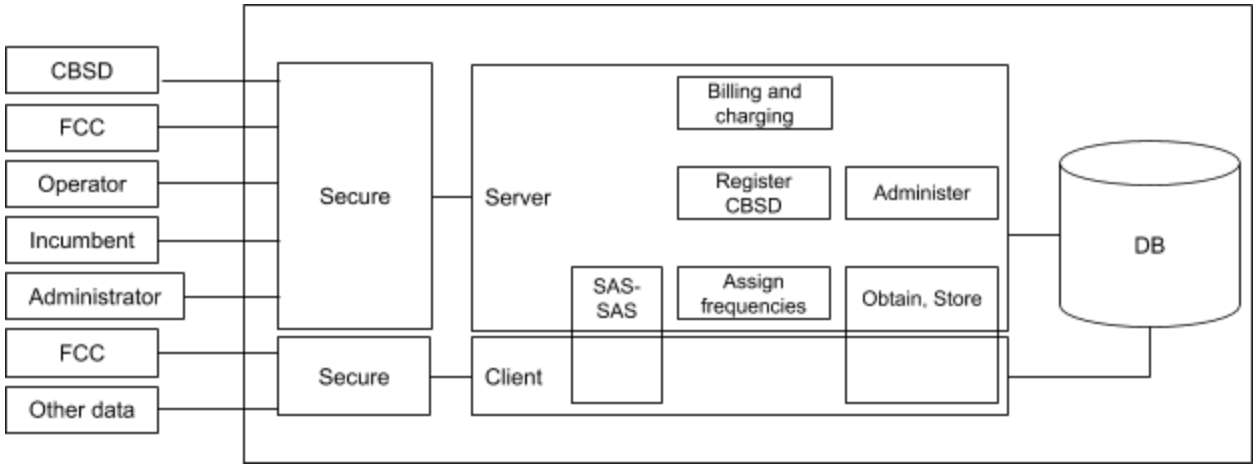

Figure 5.4 Mapping of SAS functions in Fairspectrum SAS application

5.4 Priority Access License (PAL) database

Fairspectrum populates and maintains PAL database in cooperation with other SAS Administrators. Fairspectrum PAL database follows the technical specification WINNF-TS-0245[65] or its latest version. The current version 1.0.0 of April 3, 2017 contains the following functionalities: PAL database creation and use, Record encoding for the PAL database including PAL database records, and PAL database schema definition with PAL database info record. PAL database creation and use specifies PAL Auction results, PAL channel assignment, Use of the PAL database, and leasing information in the PAL database.

6 Propagation model

"A description of the propagation model and any other assumptions that the prospective SAS Administrator or ESC operator proposes to use to model operations and facilitate coordination in the band."

Fairspectrum SAS will use the propagation models as defined in WINNF-TS-0112[66] for calculating the PAL/GWPZ protection contours and aggregate interference on FSS, GWBL or ESC receiver. The

[65] WINNF-TS-0245 Version 1.0.0. PAL Database. 26 July 2017.
[66] WINNF-TS-0112 V1.4.1 CBRS Operational and Functional Requirements. Working Document.16 January 2018.

selection of either ITM model in point-to-point mode[67] or extended Hata model (eHata)[68] depends on various conditions. For CBRS to incumbent receiver distances $d \leq 0.1$ km, the free-space path loss, as defined in WINNF-TS-0112, is used. For $0.1 < d < 1.0$ km, the eHata model without site-specific corrections is used. For $1.0 \leq d \leq 80.0$ km, the ITM model is used if the path loss using the ITM model using reliability and confidence factors of 0.5 is greater than the corresponding path loss using the eHata model. For $d > 80$ km, the ITM model is used. The distance d is calculated according to the methodology described in WINNF-TS-0112.[69] The Vincenty's Inverse Solution is used to find the distance and azimuth (used in determining the antenna gains) between transmitter and receiver. The Vincenty's Forward Solution is used to find latitude and longitude coordinates along the propagation path. The coordinates, in turn, are used to query the terrain elevations from the Fairspectrum topographical database to be used in the path loss calculations.

Furthermore, if the CBRS effective antenna height, h_b, is greater than 200 m or if the clutter category, *r*, is "rural" at the location of the CBSD, the ITM model is used independent of the distance. For path lengths between the CBSD and victim receiver $d < 3$ km, h_b is the height of the CBSD, h_{cbsd}. For path lengths $3 \leq d \leq 15$ km, h_b is the CBSD antenna height h_{cbsd} + (d-3)/12 times the difference between the terrain elevation at the CBSD antenna and the average terrain elevation over a distance of 3 km to the location of the receiver. For $d > 15$ km, h_b is the CBSD antenna height h_{cbsd} + the difference between the terrain elevation at the CBSD and the average terrain elevation over the range 3 – 15 km. Moreover, h_b is restricted to be at least 20 m independent of the calculated effective receiver height.
These models have been adapted to the Fairspectrum SAS as an internal part of the software. Fairspectrum is open to WINNF suggestion per FCC approval on the used propagation model and will implement other models whenever proposed by the regulative and standardization bodies.

[67] NTIA – ITS Irregular Terrain Model (ITM) (Longley-Rice) (20MHz-20 GHz): http://www.its.bldrdoc.gov/resources/radio-propagation-software/itm/itm.aspx
[68] NTIA. 3.5 GHz Exclusion Zone Analyses and Methodology Available at https://www.ntia.doc.gov/report/2015/35-ghz-exclusion-zone-analyses-and-methodology
[69] WINNF-TS-0112 V1.4.1 CBRS Operational and Functional Requirements. Working Document. 16 January 2018.

7 SW update

"A description of the methods that will be used to update software and firmware and to expeditiously identify and address security vulnerabilities."

As an operating system and server platform, Fairspectrum utilizes widely used and actively maintained software components. Security vulnerabilities in the platform are typically fixed fast and batches are notified and made available promptly. Fairspectrum continuously upgrades the platform software to the latest version. Fairspectrum monitors the operation of its own software components and, in a case of found security vulnerability, the software is upgraded immediately.

The platform software is upgraded using the commonly available software upgrade tools like apt-get, and the upgrade features of the platform software components. Fairspectrum's own software testing and upgrading has the following phases: development environment, server testing environment, at minimum dual instance update for software updates, and maintenance break or intermediate server arrangement for such updates, which cannot be carried out during operation. Fairspectrum develops software in a virtual environment on personal software development workstations. The virtual environment resembles the production server. The software version control management is carried out on a Fairspectrum private git server. Fairspectrum runs a limited replica of the production server as a testing server. The access to the testing server is restricted, but compared to workstation based development environment, it allows online testing. The software releases, which are selected to go to production server, are transferred there using ssh, sftp, and scp. When possible, the software changes are done instance-by-instance taking them away from load balancer list of server instances and after upgrades, returning them on the list. This way, most software upgrades can be carried out on the production server without server breaks. If the upgrades are such that the changes cannot be made online, we study if a temporary server could be used during the production server upgrade. As the final option, Fairspectrum will have a service break during upgrade.

8 Affirmation to comply

"An affirmation that the prospective SAS Administrator and/or ESC operator (and its respective SAS and/or ESC) will comply with all of the applicable rules as well as applicable enforcement mechanisms and procedures."

Fairspectrum affirms that it will comply with all of the applicable rules, applicable enforcement mechanisms, and procedures regarding SAS operation.

Fairspectrum affirms that it will comply with all applicable international agreements (§96.53(n)).

9 Information verification

"A detailed description of how the SAS will retain, secure, and verify information from CBSDs (including location data), licensees, associated ESCs, and other SASs."

9.1 CBSDs

Fairspectrum follows the security practices of WINNF-TS-0065[70] or its latest version and WINNF-TS-0071[71] or its latest version. The authorization is based on §96.49. Fairspectrum utilizes the hooks for information verification and authorization provided by WINNF-TS-0247.[72] The CBSD verification is based on Public Key Infrastructure (PKI) and Certificate Authority verification. The content of the CBSD information is checked field by field to insure that it is correct type and within the limits of the allowed values. The blacklisted devices and users are checked before authorization. Fairspectrum uses the encryption option of the Amazon RDS DataBase (DB) instance. This option encrypts the storage of the DB instance, automated backups, and read replicas and snapshots. The encryption uses the AES-256 encryption algorithm. The Fairspectrum processing environment deploys perimetry security, having load balancers only accessible from public Internet with or without passwords. The application servers are accessible only from load balancers or with SSH/SCP/SFTP RSA PKI keys from the Fairspectrum development and management workstations. The highest level of

[70] WINNF-TS-0065 Version 1.1.0. 26 July 2017. CBRS Communications Security Technical Specification.
[71] WINNF-TS-0071 Version 1.0.0. 26 July 2017. CBRS Operational Security Technical Specification.
[72] WINNF-TS-0247 V1.0.0 CBRS Certified Professional Installer Accreditation. 18 October 2017.

security is used for database, which is only accessible from the application servers and the database only listens to specified IP addresses. The connections between database and the application servers are secured by TLS connection. The database is located in the same Amazon Virtual Private Cloud as the application servers and no database ports are open to public internet. The access authorizations, key management and other related processes are according to the security controls of ISO/IEC 27001:2013(en)[73] and ISO/IEC 27002:2013(en[74]). The data is checked time to time by a Fairspectrum administrator in text format to spot any abnormal entries. Fairspectrum has a map visualization tool, which is also used by the administrator to verify the unusual location based data. Where possible, Fairspectrum carries out automated verification for the data.

9.2 Licensees

Fairspectrum will have a business relationship with the licensees. When the business relationship is formed, the validity of the licensee is checked, for example, by comparing the company registration number to the official company registry, checking who has the right to sign on behalf of the organization based on the the articles of association stored in the official company register, and checking the identity of the signing person and the position of the person in the organization. In the signed agreement with the licensee, the licensee person(s) with rights to handle licensee data is named and the clauses to ensure correctness and avoid misuse of the CBRS system are confirmed. After signing the agreement, the respective keys and certificates to enter, administer, and maintain licensee data are given to the agreed persons of the licensee. All licensee actions are authenticated, authorised, and access logs are stored. The technical compatibility is tested and verified before operation of a production SAS-licensee system.

9.3 Associated ESCs

Fairspectrum has a business relationship with the ESC administrators. When the business relationship is formed, the validity of the ESC administrator is checked, for example, by comparing the company

[73] ISO/IEC 27001:2013(en) Information technology. Security techniques. Information security management systems. Requirements.
[74] ISO/IEC 27002:2013(en) Information technology. Security techniques. Code of practice for information security controls.

registration number to the official company registry, checking who has the right to sign on behalf of the organization based on the the articles of association stored in the official company register, checking the identity of the signing person and the position of the person. In the signed agreement with the ESC administrator, the ESC administrator person(s) with rights to handle ESC data is named and the clauses to ensure correctness and avoid misuse of the CBRS system are confirmed. After signing the agreement, the respective keys and certificates to enter, administer, and maintain ESC data are given to the agreed persons of the ESC provider. Fairspectrum checks from FCC that the ESC administrator is authorized to operate an ESC service. All ESC administrator actions are authenticated, authorised, and access logs are stored. The technical compatibility is tested and verified before operation of a production SAS-ESC system. Acquired data from the ESC is never used for analytical purpose and data is never tracked or archived.

9.4 Other SASs

Fairspectrum has a business relationship with other SAS providers. When the business relationship is formed, the validity of the SAS provider is checked, for example, by comparing the company registration number to the official company registry, checking who has the right to sign on behalf of the organization based on the the articles of association stored in the official company register, checking the identity of the signing person and the position of the person. In the signed agreement with the SAS provider, the SAS provider person(s) with rights to handle SAS data is named and the clauses to ensure correctness and avoid misuse of the CBRS system are confirmed. After signing the agreement, the respective keys and certificates to enter, administer, and maintain SAS data are given to the agreed persons of the ESC provider. Fairspectrum checks from FCC that the SAS provider is authorized to operate a SAS service. All SAS provider actions are authenticated, authorised, and access logs are stored. The technical compatibility is tested and verified before operation of a production SAS-SAS system.

10 Interference resolving

"A demonstration that the SAS will be capable of resolving various sources of interference between and

among Citizens Broadband Radio Service users and/or Incumbent users."

Fairspectrum supports the reporting requirements set in WINNF-TS-0096[75] or its latest version. Fairspectrum follows and implements the Wireless Innovation Forum SSC WG1 Exception Management Task Group recommendations how trouble tickets and exceptions are managed, including FCC input, reports from incumbents, and reports from PAL. Fairspectrum provides an interface for the FCC, incumbents including operators of FSS earth stations, grandfathered licenses, PALs, GAAs and administrators of other SAS and ESC. There is a free form available for reporting about possible interference incidents. The interference incident reports will be provided to other SAS administrators and to the FCC. Fairspectrum helps the FCC and other SAS administrators to identify the cause of interference, to solve the interference issue immediately, and to make any required changes to avoid such interference incidents in the future.

11 Interference protection methods

"A description of how the SAS will ensure that non-federal FSS earth stations and grandfathered 3650-3700 MHz licensees are protected from harmful interference consistent with the rules."

This section addresses the interference protection mechanisms to prevent harmful interference towards the incumbents and Priority Access Licensees. Fairspectrum SAS does not authorize operation of CBSDs within Protection Zones except as set forth in §96.15.

11.1 Federal incumbent protection

For federal Incumbent Users operating in band 3550-3650 MHz, the Fairspectrum SAS provides protection in the following way: CBSDs and End User devices (EUD) must not cause interference towards the federal Incumbent Users authorized to operate in the 3550-3700 MHz band and below 3550 MHz, and they must accept possible interference from Incumbent Users. For Category A CBSDs, the Fairspectrum SAS will maintain up-to-date information about the EZs along the US coastline and

[75] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.

around federal radiolocation sites using the NTIA data[76] as described in the section 5.1 CBRS architecture of this document. Exclusion Zone protection methodology is applied until one or more ESCs are approved, which effectively changes the protection type to Protection Zone. Fairspectrum SAS may authorize Category A CBSDs geographic areas outside the Exclusion Zones if all the other protection criteria are met and before ESC(s) are approved. Furthermore, once an ESC is approved and used by at least one SAS, the Fairspectrum SAS authorizes CBSD transmissions based on the information provided by an approved ESC. Category B CBSDs are only authorized when information about the federal incumbent use is present and provided to the Fairspectrum SAS by an approved ESC. Within no more than 300 seconds after the ESC has observed presence of an federal Incumbent User, the Fairspectrum SAS ensures that the CBSDs are suspended or moved to another frequency. Moreover, If the President of the United States or another Federal Government body instructs to discontinue the use of CBSDs, the Fairspectrum SAS instructs the CBSDs to cease all communication. Fairspectrum SAS will adapt to changes in the federal EZs and PZs to protect current or future federal Incumbent Users as requested by the FCC either on temporal or continuous basis.

For federal Incumbent Users operating in band 3650-3700 MHz, the Fairspectrum SAS provides protection in the following way: CBSDs and End User devices (EUD) must not cause interference towards the federal Incumbent Users authorized to operate in the 3550-3700 MHz band and below 3550 MHz, and must accept possible interference from Incumbent Users. The Fairspectrum SAS will maintain up-to-date information about the EZs 80 km radius around the federal radiolocation sites listed in §90.133 and §2.106. Exclusion Zone protection methodology is applied until one or more ESCs are approved, which effectively changes the protection type to Protection Zone. The Fairspectrum SAS is consistent about the information of the presence of federal Incumbent User provided by an approved ESC, and enforces this information when authorizing the CBSD transmission within the PZ. Within no more than 300 seconds after the ESC has observed presence of an federal

[76] NTIA 3550-3650. NTIA. Spectrum Management. 3550-3650 MHz. Available at https://www.ntia.doc.gov/category/3550-3650-mhz.

Incumbent User, the Fairspectrum SAS ensures that the CBSDs are suspended or moved to another frequency. Moreover, If the President of the United States or another Federal Government body instructs to discontinue the use of CBSDs, the Fairspectrum SAS instructs the CBSDs to cease all communication.

11.2 PAL protection

The PAL licensees are auctioned by the FCC, where each PAL licensee is assigned to a census tract. Subsequently, the PALs are registered in the system and the Fairspectrum SAS verifies each individual PAL using the PAL-ID, User Registration Identity (UR-ID), FCC tract identity information (which census tract is assigned to the PAL), and frequency channel logical identity information (which frequencies are auctioned to the PAL).

The Fairspectrum SAS provides PAL protection in the 3550-3650 MHz band by using the information of the PALs obtained from the FCC together with the relevant data described in 5.1 CBRS architecture. The data includes land clutter data and elevation data in order to calculate the PPA for both -96 dBm and -80 dBm contours. PAL licensees can also choose to report a PPA that is smaller in geographical area than the area calculated by the Fairspectrum SAS. The Fairspectrum SAS assigns each PAL to a census tract and channel, as specified in section 1.3 Assigning frequencies of this document. The Fairspectrum SAS manages subsequent CBSD transmissions so that the aggregate interference of the GAA CBSDs within 40 km of the PPA is below -80 dBm/MHz for all points in the protection area.

The Area-Protection-Reference-Standard is described as follows: A fixed grid spanning candidate CBSD locations is defined. The grid has points separated by 2 arcseconds in north/south and east/west directions. The grid is aligned to integer latitude and longitude lines. The protection area is defined by a set of bounding contours. Protection points of a protection area are grid points of the fixed grid within the protection area. Protection to this area provided by a SAS ensures that estimated aggregate interference falls below the predefined limit at each protection point. The aggregate interference

calculations are performed assuming the use of an isotropic antenna integrating over a 10 MHz bandwidth and using a specified elevation above ground level.

As a result of a conservative SAS estimate, that aggregate interference from interfering CBSDs is expected to be less than or equal to a specified protection level for all protection points.

11.3 FSS and GWBL protection

"A description of how the SAS will ensure that non-federal FSS earth stations and grandfathered 3650-3700 MHz licensees are protected from harmful interference consistent with the rules."

Fairspectrum does not allow CBSDs to operate within areas that may cause interference to FSS earth station above the levels described in § 96.17(a) and (b), provided that the licensee of the FSS earth station and the authorized user of the CBSD mutually agree on such operation and the terms of any such agreement are provided to Fairspectrum according to § 96.17(e).

The Fairspectrum SAS provides incumbent protection in the 3650-3700 MHz band by using the information of the FSS and GWBL in the database together with the relevant data described in section 5.1 CBRS architecture. The information includes land clutter data and elevation data, and the information about the CBSD making the request such as geolocation and transmit antenna configuration parameters. The purpose is to calculate the aggregate interference originated from the CBSDs located within 150 km for co-channel FSS, 40 km for adjacent channel FSS, and 40 km for Grandfathered Wireless Protection Zones (GWPZ), by using the propagation models as defined in section 6 Propagation model. The procedure for FSS operating in the 3600-3700 MHz is as follows:

1. Calculate the CBSD antenna gain towards the victim FSS receiver. This is obtained by determining the angle between the axis of the main beam of the CBSD towards the FSS receiver and the corresponding antenna gain using the radiation pattern reported by the CBSD. If the radiation pattern is not reported, the generic formula for the antenna gain given in WINNF-TS-0112[77] is used.

[77] V1.4.1 CBRS Operational and Functional Requirements. Working Document. 16 January 2018.

2. Calculate the FSS antenna gain towards the CBSD. This is obtained by determining the angle between the axis of the main beam of the FSS towards the CBSD and the corresponding antenna gain using the radiation pattern reported by the FSS.
3. Calculate the path loss between the CBSD and FSS using the propagation model chosen with the criteria given in section 6 Propagation model. The calculation utilizes transmitter/receiver antenna height information, land clutter class at the location of the CBSD, and the elevation data along the propagation path.
4. Estimate the received aggregate interference level at the FSS receiver by taking into account the antenna gains as described above, the maximum EIRP reported by the CBSD in the registration or grant request, and signal losses. The root mean squared (RMS) of the aggregate interference of the CBSDs within 150 km from the FSS location is not permitted to exceed -129 dBm / MHz for co-channel, or -60 dBm for adjacent channel blocking CBSDs within 40 km from the FSS location. If the received interference power falls below these limits in the co/adjacent channels, the CBSD is permitted to transmit with the reported operational parameters.

Moreover, for protection calculations of FSS operating in the 3700-4200 (out-of-band), Fairspectrum uses an equivalent methodology and will ensure that aggregate interference of the CBSDs within 40 km stays below the predefined thresholds as given in WINNF-TS-0112.[78] FSS licensees operating in the 3600-3700 Mhz and in 3700-4200 MHz can also request for additional protection from Fairspectrum SAS through a dedicated informing interface build in the Fairspectrum SAS.

The protection of the existing GWBL operators in the 3650-3700 MHz corresponds to the methods presented for PAL and FSS. However for GWBL, the protection zone GWPZ is calculated as described in WINNF-TS-0112. The GWBLs can operate within their GWPZ area. The aggregate interference from CBSDs within 40 km from the protection points, defined using the Area-Protection-Reference -Standard described in section 11.2 PAL protection, is then calculated using the methodology described in the four steps above, and shall not exceed -80 dBm/10 MHz in any point in the GWPZ. Furthermore,

[78] WINNF-TS-0112 V1.4.1 CBRS Operational and Functional Requirements. Working Document. 16 January 2018.

the Fairspectrum SAS ensures that the GWBL shall not cause harmful interference to the existing grandfathered FSS earth stations operating in the 3650-3700 MHz, nor to the federal Incumbent Users until the last Grandfathered Wireless Broadband Licensee's license expires.

11.4 ESC protection

The Fairspectrum SAS provides ESC sensor protection as needed. The ESC operator can require protection by providing the geolocation, antenna height, radiation pattern, antenna gain, and other relevant information from the sensor to Fairspectrum SAS, which then calculates the aggregate interference from all CBSDs within 40 km from the sensor location and manages the CBSD transmission so that the interference falls below 107 dBm/MHz – PL (Path Loss) + GESC, where GESC is the maximum gain of the ESC sensor antenna.

12 SAS to SAS

"A description of how coordination will be effectuated (e.g., through data synchronization) between multiple SASs, if multiple SASs are authorized, and how quickly this synchronization of data will be accomplished."

Fairspectrum supports WINNF-TS-0096[61] or its latest version for SAS to SAS communication. The version 1.0.0 from Nov 29, 2016 contains the following procedures: SAS mutual authentication and security, record exchanges, and message flow. The SAS-SAS synchronization has support for time-range requests, By-ID requests, push and full record dump. The document specifies the message encoding, transport, and contents aggregation. The supported messages include: SAS administrator, SAS Implementation, CBSD Device Type, CBSD Data, Incumbent Protection Data, ESC Sensor, Zone definition, Coordination event, and full activity dump. Fairspectrum will carry out the test and certification process as described in WINNF-TS-0061[79] or in its latest version. The current version 1.0.0 of Jan 15, 2017 contains the following functional tests: SAS-SAS security, authentication, and encryption protocols, SAS-SAS Administrator record exchange, SAS-SAS CBSD device type record, SAS-SAS CBSD registration data message, SAS-SAS incumbent protection SAS message, SAS-SAS

[79] WINNF-TS-0061 Version 1.1.0 WG4 SAS Test and Certification Specification. 26 January 2018.

Zone record exchange, SAS-SAS coordination event message, and SAS-SAS full activity dump message.

13 Other SAS entities

"If the prospective SAS Administrator will not be performing all SAS functions, it must provide information on the entities operating other functions and the relationship between itself and these other entities. In particular, it must address how the Commission can ensure that all of the requirements for SAS Administrators in Part 96, subpart F are satisfied when SAS functions are divided among multiple entities, including a description of how data will be transferred among these various related entities and SASs, if multiple SASs are authorized, and the expected schedule of such data transfers (i.e., real-time, once an hour, etc.)."

The Fairspectrum SAS will provide all SAS functions.

14 Protocols

"A description of the methods (e.g., interfaces, protocols) that will be used by: (1) CBSDs to communicate with the SAS; (2) the SAS to communicate with CBSDs; (3) the SAS to communicate with other SASs; and, if applicable, (4) the SAS to communicate with one or more ESCs. The prospective SAS Administrator must also describe the procedures, if any, which it plans to use to verify that a CBSD can properly communicate with the SAS."

14.1 CBSD - SAS - CBSD

The Fairspectrum SAS uses the WINNF-TS-0016[80] or its latest version, Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS): Spectrum Access System (SAS) - Citizens Broadband Radio Service Device (CBSD) Interface Technical Specification. The architecture of the SAS-CBSD protocol can be found in Figure 14.1. A domain proxy can group messages of several CBSDs, which are administered by the domain proxy. From Internet client-server perspective, SAS is the server and domain proxy or CBSD is the client.

[80] WINNF-TS-0016 Version 1.2.1 SAS to CBSD Protocol Specification. 3 January 2018.

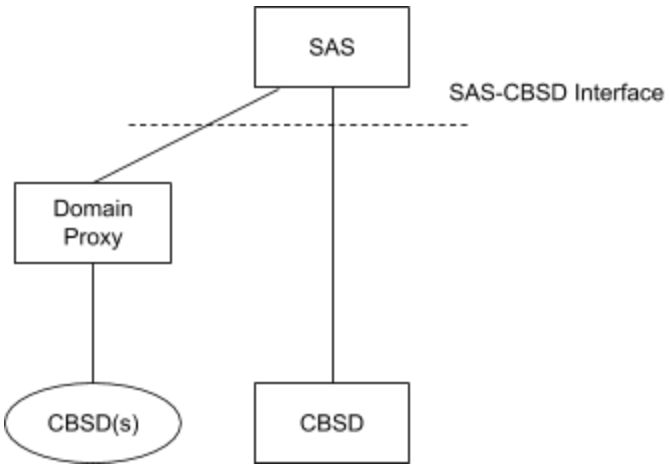

Figure 14.1. SAS-CBSD protocol architecture according to WINNF-TS-0016[64]

The 1.0.1 version (Dec. 22, 2016) of the specification contains the following procedures: Pre-requisite procedures, SAS Discovery, Authentication, CBSD Registration, CBSD Spectrum Inquiry, CBSD Grant, CBSD Heartbeat, CBSD Grant Relinquishment, and CBSD Deregistration. The messages are encoded using JavaScript Object Notation (JSON) according to RFC-7159[81] and transported with TLS. Multiple data elements can be aggregated in a single request.

14.2 SAS - SAS

The Fairspectrum SAS uses the WINNF-TS-0096[82] or its latest version, Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS): Spectrum Access System (SAS) - SAS Interface Technical Specification. The 1.0.0 version (29 November 2016) of the specification contains a description of SAS-SAS prerequisites. The specified procedures include SAS mutual authentication and communications security based on TLS, record exchanges, and message flow. SAS-SAS synchronization contains time-range request support, By-ID request support, push support, and full record dump. Message encoding and transport are based on JSON and TLS. From Internet client-server perspective, each SAS operates as a server and as a client. The SAS is both able to make requests and respond to requests. The data can be carried both in request and in response, see Figure 14.2.

[81] RFC-7159. The JavaScript Object Notation (JSON) Data Interchange Format.
[82] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.

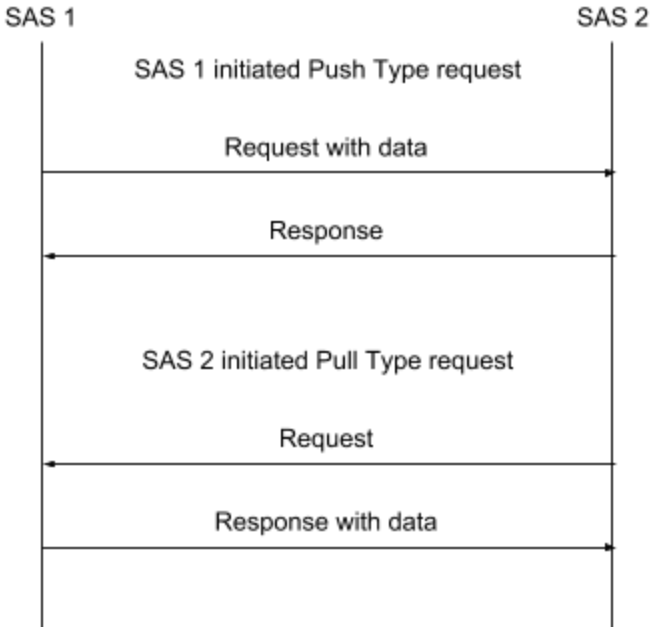

Figure 14.2. SAS-SAS message exchanges, data in request and response according to WINNF-TS-0096 [83]

14.3 SAS - ESC

The Fairspectrum SAS will integrate with the selected ESC provider. Fairspectrum implements the ESC provider's SAS-ESC interface. On a high level, the interface includes mutual authentication (TLS assumed). Communication over the interface is encrypted. ESC processes the sensor information and in the case of federal Incumbent User, ESC makes a notification to SAS. The notification contains information about the location and frequency channels. The Fairspectrum SAS computes and executes the required changes in PAL and GAA use to protect federal Incumbent User from harmful interference. The restrictions are maintained until ESC makes another notification that releases the restrictions. Fairspectrum assumes that Open source Standard Spectrum Resource Format (OpenSSRF) [84] is utilized in describing the spectrum resources.

[83] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.
[84] Open source Standard Spectrum Resource Format. See,http://openssrf.org/.

15 Comply 96.55

"An affirmation that, consistent with section 96.55 of the Commission's rules, the SAS will only retain records and information or instructions received regarding federal transmissions from the ESC in accordance with information retention policies established as part of the ESC approval process."

Fairspectrum affirms that consistent with section 96.55 of the Commission's rules, the Fairspectrum SAS will only retain records and information or instructions received regarding federal transmissions from the ESC in accordance with information retention policies established as part of the ESC approval process.

16 Access authorization

"A description of the security methods that the prospective SAS Administrator plans to use to ensure that unauthorized parties cannot access or alter the SAS or otherwise corrupt the operation of the SAS in performing its intended functions, consistent with the Commission's rules."

Fairspectrum follows the security guidelines of WINNF-TS-0065[85] or its latest version and WINNF-TS-0071[86] or its latest version. Fairspectrum IT security controls are based on ISO/IEC 27001:2013(en)[87] and ISO/IEC 27002:2013(en).[88] The authorization is based on §96.33. Fairspectrum deploys SAS-ESC communication security the in the same way as SAS-SAS communication. The authentication is mutual PKI certificate authentication using TLS-V1.2 (RFC-5246[89]) and follows the policy of WINNF-TS-0022.[90] The communication is encrypted and the used ciphersuite is one from the list of WINNF-TS-0096[91] or its latest version, for example, TLS_RSA_WITH_AES_128_GCM_SHA256. Both SAS and ESC validate certificates according to

[85] WINNF-TS-0065 Version 1.1.0. 26 July 2017. CBRS Communications Security Technical Specification..
[86] WINNF-TS-0071 Version 1.0.0. 26 July 2017. CBRS Operational Security Technical Specification.
[87] ISO/IEC 27001:2013(en) Information technology. Security techniques. Information security management systems. Requirements
[88] ISO/IEC 27002:2013(en) Information technology. Security techniques. Code of practice for information security controls.
[89] RFC-5246. The Transport Layer Security (TLS) Protocol Version 1.2. Available at https://www.ietf.org/rfc/rfc5246.txt.
[90] WINNF-TS-0022 Version 1.1.2. CBRS PKI Certificate Policy. 6 February 2018..
[91] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.

RFC-5280.[92]

Fairspectrum registers, authenticates and authorizes CBSDs. Fairspectrum checks the blacklisted devices before any authorization. Before allowing an entity to register CBSDs, the entity needs to create a partnership with Fairspectrum. As part of the partnership, Fairspectrum or a certificate authority provides the partner with credentials, which are required to register CBSDs. The CBSD registration is carried out with Registration procedure of WINNF-TS-0016[93] or its latest version. Authentication is carried out with Authentication procedure WINNF-TS-0016[72] or its latest version. The mutual authentication is based Public Key Infrastructure and certificates (RFC-5280[94]) on TLS-v1.2 (RFC-5246) and it takes into account the policy of WINNF-TS-0022.[95] The authentication follows the guidelines set in WINNF-15-P-0065 or its latest version. For all FCC Identifiers intending to register, Fairspectrum checks the validity of the ID from the Commission's Equipment Authorization System. Only registered and authenticated CBSDs are authorized to use the Fairspectrum SAS service. A Domain Proxy may represent a number of CBSDs according to WINNF-TS-0016[72] or its latest version. When federal incumbents are protected with Protection Zones, Fairspectrum only authorizes CBSDs within the Protection Zones based on ESC information according to §96.67. Fairspectrum computes and utilizes PAL Protection Areas according to §96.25 and relevant WINNF specifications.

Fairspectrum follows the security practices of WINNF-TS-0065[96] or its latest version and WINNF-TS-0071[97] or its latest version. The CBSD verification is based on Public Key Infrastructure (PKI) and Certificate Authority verification. The content of the CBSD information is checked field by field that it is correct type and within the limits of the allowed values. Fairspectrum uses encryption

[92] RFC-5280. Internet X.509 Public Key Infrastructure Certificate and Certification Revocation List (CRL) Profile. Available at https://www.ietf.org/rfc/rfc5280.txt.
[93] WINNF-TS-0016 Version 1.2.1 SAS to CBSD Protocol Specification. 3 January 2018.
[94] RFC-5280. Internet X.509 Public Key Infrastructure Certificate and Certification Revocation List (CRL) Profile. Available at https://www.ietf.org/rfc/rfc5280.txt.
[95] WINNF-TS-0022 Version 1.1.2. CBRS PKI Certificate Policy. 6 February 2018.
[96] WINNF-TS-0065 Version 1.1.0. 26 July 2017. CBRS Communications Security Technical Specification.
[97] WINNF-TS-0071 Version 1.0.0. 26 July 2017. CBRS Operational Security Technical Specification.

option of Amazon RDS DB instance. This option encrypts the storage of the DB instance, automated backups, read replicas, and snapshots. The encryption uses AES-256 encryption algorithm. Fairspectrum processing environment deploys perimetry security, having load balancers only accessible from public Internet with or without passwords. The application servers are accessible only from load balancers or with SSH/SCP/SFTP RSA PKI keys from the Fairspectrum development and management workstations. The highest level of security is for database, which is only accessible from the application servers, which are located in the same Amazon Virtual Private Cloud. The access authorizations, key management and other related processes are according to the security controls of ISO/IEC 27001:2013(en)[98] and ISO/IEC 27002:2013(en).[99] The data is checked time to time by a Fairspectrum administrator in text format to spot any abnormal entries. Fairspectrum has a map visualization tool, which is also used by the administrator to verify the unusual location based data. Where possible, Fairspectrum carries out automated verification for the data.

17 Use-case scenarios

"Descriptions of dynamic use-case scenarios for how the SAS will manage and assign spectrum resources to ensure that geographically and spectrally adjacent operations are coordinated consistent with the Commission's rules. Use case scenarios should include the methodology and protection approach for cases of radio interference due to adjacent blocking, out-of-band emissions, and aggregate co-channel interference. Describe how multiple SASs will coordinate the calculation of aggregate interference for protecting Incumbent users and Priority Access licensees."

Fairspectrum SAS interoperates with multiple SASs in order to provide the interference protection as described in section 11 Interference protection methods so that geographically and spectrally adjacent operations are coordinated consistent with the Commission's rules. The interoperation is based on information exchange over SAS-SAS interface according to specification WINNF-TS-0096[100] or its

[98] ISO/IEC 27001:2013(en) Information technology. Security techniques. Information security management systems. Requirements.
[99] ISO/IEC 27002:2013(en) Information technology. Security techniques. Code of practice for information security controls.
[100] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.

latest version. Two scenarios are presented: 1) The use case describes how the Fairspectrum SAS coordinates with other SASs to provide protection for Incumbent Users given the constraints on co-channel, adjacent channel blocking and out-of-band emissions. 2) The use case describes a scenario where the Fairspectrum SAS coordinates with other SASs to manage the transmission of GAA CBSDs in order to satisfy the interference constraints on PPAs of PAL users.

17.1 Use case 1: coordinated incumbent protection

There are the Fairspectrum SAS, SAS_A, and SAS_B in the example of use case 1. They are located in the studied area as illustrated in Figure 17.1. The example has a single FSS ground station and a single GWBL operating at frequencies f_i and f_j, respectively. Fairspectrum SAS manages three CBSDs in the bottom sector of the area. One of the CBSDs is within 40 km from FSS at adjacent frequency channel to f_i, one is within the distance of 150 km from FSS at co-channel frequency f_i, and one is beyond 150 km from FSS and within 40 km from the GWPZ protection contour of GWBL at GWBL co-channel frequency f_j. SAS_A controls two CBSDs in the up-left sector. One of the CBSDs is within 40 km from FSS at adjacent frequency channel of f_i and one is within the distance of 150 km from FSS at co-channel frequency f_i. SAS_B operates two CBSDs in the sector on the up-right. One of the CBSDs is within 40 km from FSS at adjacent frequency to f_i and one is within the distance of 150 km from FSS at co-channel frequency f_i. Fairspectrum SAS gets a grantRequest for frequency f_i from a new CBSD, marked as "New CBSD" in Figure 17.1.

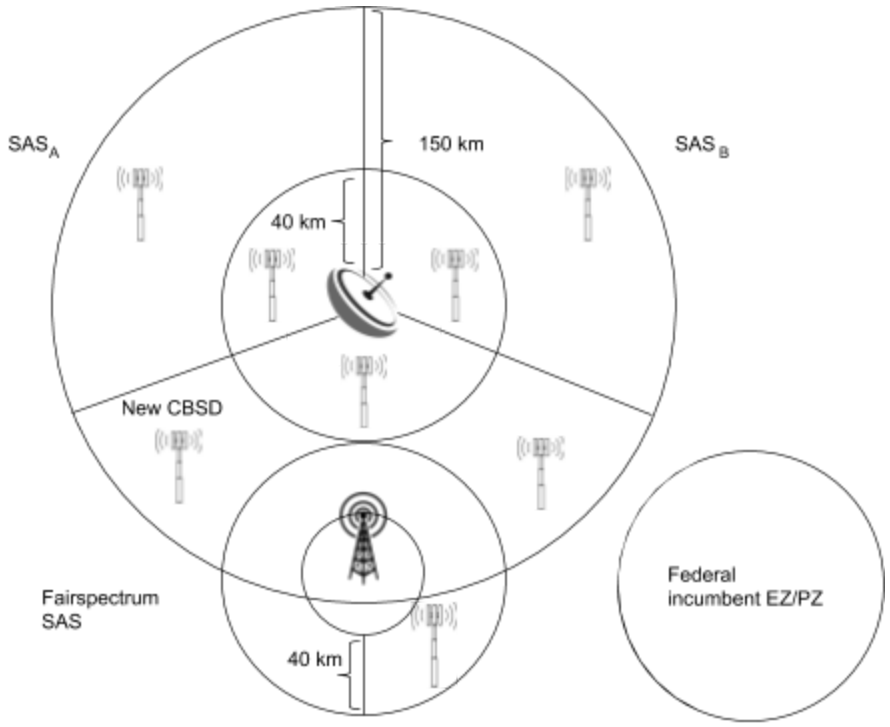

Figure 11.1. Coordinated incumbent protection of Fairspectrum SAS and two other SASs

Fairspectrum SAS, SAS_A, and SAS_B mutually coordinate the interference protection. Fairspectrum SAS, SAS_A, and SAS_B exchange incumbent information over SAS-SAS interface according to specification WINNF-TS-0096[101], ensuring that each SAS has the latest incumbent information. Fairspectrum SAS, SAS_A, and SAS_B also ensure that each SAS has the latest CBSD information by exchanging CBSD information over SAS-SAS interface.

Fairspectrum SAS assigns operating parameters for the new CBSD using e.g. the Iterative Allocation Process methodology described in WINNF-TS-0112[102], or a similar method approved by the FCC. Fairspectrum SAS allocates the spectrum resources equally while satisfying the interference constraints. Fairspectrum SAS computes the allowed operating parameters so that the aggregate interference threshold for co-channel FSS -129 dBm/10 MHz (RMS), as defined in WINNF-TS-0112

[101] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.
[102] WINNF-TS-0112 V1.4.1 CBRS Operational and Functional Requirements. Working Document. 16 January 2018.

[103], is not exceeded. Similarly, for adjacent channel blocking the interference threshold is -60 dBm (RMS). Fairspectum SAS ensures that the aggregate interference does not exceed the adjacent channel threshold. In calculation of adjacent channel blocking at the FSS receiver, the SASs consider the receive filter characteristics according to the FSS spectral mask. In addition, the out-of-band emissions to FSS operating at 3700-4200 MHz and to other incumbents operating outside the 3550-3700 band are taken into account in the calculations and in the subsequent CBSD responses. The incumbent information can be obtained directly by Fairspectrum SAS or through other SAS operators. Fairspectrum SAS takes into account self acquired CBSD information and CBSD information, which was received in the information exchange with other SASs in the aggregate interference computation.

Note that the CBSD (lowest in the figure) is located outside the 150 km limit, therefore it is not taken into account in the interference calculations for FSS. However, for the GWBL operating in the center of the lower inner circle in Figure 11.1, FS SAS manages the CBSD at f_j which is within 40 km from the GWPZ protection contour so that the interference at any point in the GWPZ (lower inner circle) shall not exceed the threshold -80 dBm/10 MHz. For federal incumbent protection, the SASs either ensure that CBSDs requesting the spectrum are outside the Exclusion Zones, or if ESC(s) are operational, the aggregate interference does not exceed the Protection Zone limit.

17.2 Use case 2: coordinated PAL protection

The use case 2 describes a scenario where the Fairspectrum SAS coordinates with other SASs to manage the transmission of GAA CBSDs in order to satisfy the protection constraints on PPAs of PAL users as illustrated in Figure 11.2. The protection approach corresponds to the methodology described in the section 11.1 for GWBL.

[103] WINNF-TS-0112 V1.4.1 CBRS Operational and Functional Requirements. Working Document. 16 January 2018.

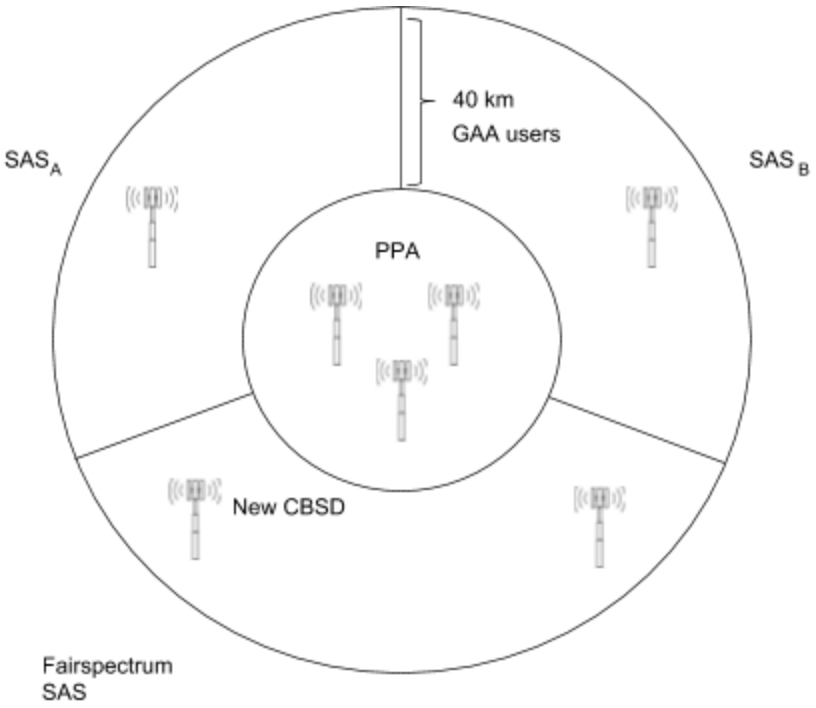

Figure 11.2. Coordinated PAL protection Fairspectrum SAS and two other SASs

Figure 17.2 contains a scenario where the Fairspectrum SAS coordinates with other SASs to manage the transmission of GAA CBSDs in order to satisfy the interference constraints on PPA of PAL users. PAL users operate within their PPA, and GAA users operate within 40 km from the closest point in the PPA protection contour. Fairspectrum SAS, SAS_A, and SAS_B exchange CBSD information over SAS-SAS interface according to specification WINNF-TS-0096[104], ensuring that each SAS has the latest CBSD information.

The PPA has been calculated by the Fairspectrum SAS and subsequently distributed among all SASs by record exchange through the SAS-SAS interface. The PAL users operate within their PPA, and GAA users operate outside PPA and within 40 km from the PPA protection contour. The aggregate interference from the GAA users must not exceed -80 dBm/10 MHz.

[104] WINNF-TS-0096 Version 1.2.0 SAS-SAS Protocol Specification. 22 October 2017.

Fairspectrum assigns operating parameters for the new CBSD using e.g. the Iterative Allocation Process methodology described in WINNF-TS-0112[105], or a similar method approved by the FCC, in order to satisfy the interference constraints in the PPA points. If there were incumbents present as in Use case 1, the response provided in spectrum request would be affected by both incumbent and PAL users. Fairspectrum SAS provides protection to self acquired PALs and for PALs, of which the information was received in the information exchange with other SASs. Fairspectrum SAS takes into account self acquired CBSD information and CBSD information, which was received in the information exchange with other SASs in the aggregate interference computation.

18 FCC interface

"A description of the methods that the SAS will use to make information stored or retained by the SAS available in response to a request from authorized Commission personnel."

Fairspectrum provides a web-based user interface for FCC. Through the interface FCC is able to check the incumbent data, registered CBSDs, log data of SAS service use, and current spectrum allocations. The queries can be narrowed based on location, time, frequency, and IDs. FCC interface allows to block and release selectable channels from GAA and PAL use on a restricted area for a defined time. Commission can set and clear a blacklist based on devices, device owners, or licenses.

[105] WINNF-TS-0112 V1.4.1 CBRS Operational and Functional Requirements. Working Document. 16 January 2018.

19. Letter from G.I.T. Telecom Limited

G.I.T. TELECOM LIMITED
Agias Fylaxeos 118, CHRISTABEL HOUSE,
P.C. 3087 Limassol, Cyprus

Limassol, Cyprus
23rd of May, 2017

TO WHOM IT MAY CONCERN

Dear Sirs,

G.I.T. TELECOM LIMITED (hereinafter referred to as "the Company") has a wide and successful experience in the area of development and implementation of international telecommunication and high-technology hardware and software. The Company is a valuable service provider in delivering internet and data access with the modern technology to emerging markets on world-wide basis.

The Company's professional team represented by high-quality specialists with significant experience of project development, deployment and exploitation of telecommunication and information technologies who are ready to utilize their expertise in order to facilitate development of telecommunication sector in different countries.

We have an investment potentiality for telecommunication sector development not only on emerging markets as it is mentioned above, but as well on the territory of Europe and USA region and we are ready to focus at investing in early-stage innovative companies with high-growth potential by ourselves or via creation of partnership with the same strategic business vision.

We always have an active participation in the Company's subsidiaries management and prefer to work closely with Director(s), CEO, CFO in order to have the best solutions for local telecommunication projects development.

Based on this approach, we would like to identify Fairspectrum Oy (hereinafter referred to as "Fairspectrum") as a high potential company and invested in it in 2014 to help it becoming the leader in telecommunication European market. We are now in the process of further consolidation with Fairspectrum for its expansion in USA and we intend to support it with sufficient funds to operate as a SAS Administrator locally. We also intend to support the Fairspectrum strategy to import the American spectrum sharing model in Europe with Fairspectrum American industry partners as soon as it starts operations in US.

G.I.T. TELECOM LIMITED
Efpraxia Lazarou
Director

Yours respectfully,

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